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Radiation practices

Annual report 2016

Riikka Pastila (ed.)

Säteilyturvakeskus
Strålsäkerhetscentralen
Radiation and Nuclear Safety Authority

STUK

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Abstract

A total of 3120 safety licences for the use of ionizing radiation were current at the end of 2016. Of these, 1600 concern dental X-ray practice. The use of radiation was controlled through regular inspections performed at places of use, test packages sent by post to dental X-ray practices and maintenance of the Dose Register. The Radiation and Nuclear Safety Authority (STUK) conducted 698 inspections of safety-licensed practices in 2016. The inspections resulted in 734 repair orders issued. In addition, radiation safety guides were published and research was conducted in support of regulatory control.

A total of 10 951 occupationally exposed workers were subject to individual monitoring in 2016, and 70 081 dose entries were recorded in the Dose Register maintained by STUK.

In 2016, regulatory control of the use of non-ionizing radiation (NIR) focused on lasers, sunbeds, radio appliances and cosmetic NIR applications. A total of 18 cases of sales or import of dangerous laser devices were found in regulatory control. Eleven on-site inspections of show lasers were conducted. Municipal health protection authorities submitted the details of the inspections of 55 sunbed facilities to STUK for evaluation and decision. In addition to this, eight sunbed facilities were surveyed on the basis of STUK's own monitoring. Eleven devices were tested in the market surveillance of wireless communication devices.

In metrological activities, national metrological standards were maintained for the calibrations of radiation meters used in radiotherapy, radiation protection and X-ray imaging. STUK's metrological laboratory performed well in the measurement comparisons with results clearly within the acceptable range. In external evaluations, the laboratory was found to comply with the requirements set for national metrological laboratories.

There were 105 abnormal events related to radiation use in 2016. Of these events, 30 concerned the use of radiation in industry and research, 70 the use of radiation in health care, two the use of radiation in veterinary medicine and three the use of non-ionizing radiation. In addition, 998 events with an estimated minor significance for safety were reported for health care.

Contents

Management review

The Department of Radiation Practices Regulation (STO) of the Radiation and Nuclear Safety Authority (STUK) functions as a regulatory authority on the use of ionizing and non-ionizing radiation, conducts research in support of regulatory control of the use of radiation, and maintains metrological standards for ionizing radiation. Regulatory control involves safety licensing, approval and registration procedures, inspections of places where radiation is used, market surveillance and monitoring of workers' radiation doses.

In 2016, the general state of radiation practice safety in health care, industry and research was relatively good. No radiation use-related serious accidents or incidents impacting the safety of patients, employees or the environment were reported to STUK.

In 2016, the number of abnormal events reported to STUK increased slightly compared with the previous year. Events with minor significance for radiation safety in the health care sector can be compiled into specific categories and reported each calendar year. There were 998 such events reported in 2016, compared with 755 in 2015.

In March, the monitoring station on the roof of the STUK building in Helsinki, included in the outdoor radiation monitoring network, detected abnormal cesium concentrations. After thorough investigation, the source of the cesium leak was located in a company situated in the same building as STUK. The company receives decommissioned radiation sources from industry and health care and forwards them for final disposal. The incident did not cause any danger to health or the environment, but cesium spread into the premises of the company and STUK, which is why extensive cleaning was necessary. STUK asked the Safety Investigation Authority to investigate the incident. The investigation report was completed early in 2017. As a result of the incident, STUK revised its radiation safety guides (ST guides) and control practices concerning the use of sealed sources, as well as its procedures related to preparedness and preparedness communication.

In 2016, altogether 14 603 workers were subject to monitoring of radiation exposure. Of these, 10 951 were subject to individual monitoring as occupationally exposed workers; nearly 8000 of them were engaged in radiation work and the rest in the use of nuclear energy. In Finland, the largest group of occupationally exposed workers, whose exposure rate is also the highest, is constituted by cockpit and cabin personnel working on aeroplanes, approximately 3600 people altogether. In 2016, there were no cases of the effective dose to a worker exceeding the annual or five-year dose limit set for workers. A collective dose of 13.65 Sv was recorded in the Dose Register in 2016 for all workers subject to monitoring of radiation exposure. Of this dose, 75% was recorded for flight personnel.

In 2016, the processing of safety licence applications and other applications was occasionally congested. However, the average processing time remained within the target range. In some cases, the maximum processing time was exceeded because of a temporary resource shortage, mainly as a result of legislative work. Along with the progress of the preparation of the social welfare and health care reform, the number of applications for amendments to safety licences has increased, as organizations are getting reorganized. Licence applications related to reorganization in the health care business sector were also more challenging than usual, which contributed to longer processing times.

The number of CT scans carried out in the health care sector has continued to increase, and the justification assessment and optimization of scans are becoming increasingly important. In the latter

part of the year, STUK participated in a joint European campaign, during which particular attention was paid to justification assessment when carrying out inspections.

The number of X-ray appliances in industry has increased considerably in the last ten years. The good news is that they have, to some extent, replaced devices that contain radioactive material; the surveillance and decommissioning of such devices is more challenging compared with X-ray appliances.

Owned by VTT Technical Research Centre of Finland and located in Otaniemi, the most significant Finnish laboratory that focuses on the researching of materials and handles radioactive materials is undergoing transformation. New facilities were completed at the VTT Centre for Nuclear Safety in 2016. In the latter part of the year, STUK granted safety licences to some of the operations to be started in the new facilities. Preparations for decommissioning the current facilities are underway.

STUK strengthened its co-operation with the other authorities responsible for monitoring the transport of dangerous goods by means such as participation in the meetings of a group of relevant authorities. In addition, a joint inspection was carried out with the police, and a number of shortcomings were detected.

Regulatory control of the use of non-ionizing radiation focused on providers of sunbed and beauty care services.

The operations of STUK's national metrological laboratory were assessed and found to clearly meet the requirements set for it. To ensure high quality, the laboratory participated in regular international measurement comparisons. The comparison results for 2016 were good.

The development of radiation safety regulations continued. STUK's contribution to the comprehensive revision of the Radiation Act was significant. The work was led by the Ministry of Social Affairs and Health. The revision is necessary in order to implement the EU directive concerning protection against dangers from ionizing radiation. The work continues in 2017. The revised Radiation Act and the related lower-level regulations are intended to enter into force as of the beginning of 2018.

STUK aims to increase research collaboration with its Finnish co-operation partners in order to ensure access to up-to-date information and a high level of expertise throughout the sector. Research collaboration developed favourably. In addition, STUK participated in a number of European research projects with objectives such as receiving new recommendations from the European Commission on the use of radiation and obtaining research data necessary for Finnish users of radiation and regulatory control.

1 General

"Use of radiation" refers to the use and manufacture of and trade in radiation equipment and radioactive materials, and to associated activities, such as possessing, safekeeping, servicing, repairing, installing, importing, exporting, storing and transporting them, and the process of rendering radioactive waste harmless. "Radiation practice" refers to radiation use and to any activity or circumstances in which human exposure to natural radiation is or may be hazardous to the health.

"Radiation" refers to both ionizing and non-ionizing radiation.

The Department of Radiation Practices Regulation (STO) at STUK is responsible for the regulatory control of the use of radiation and other practices causing exposure to radiation in Finland, while the Department of Environmental Radiation Surveillance (VALO) at STUK is responsible for the regulatory control of exposure to natural radiation excluding cosmic radiation.

1.1 Principal key figures

The principal key figures for the use of radiation and other practices causing exposure to radiation are shown in Figures 1–4.

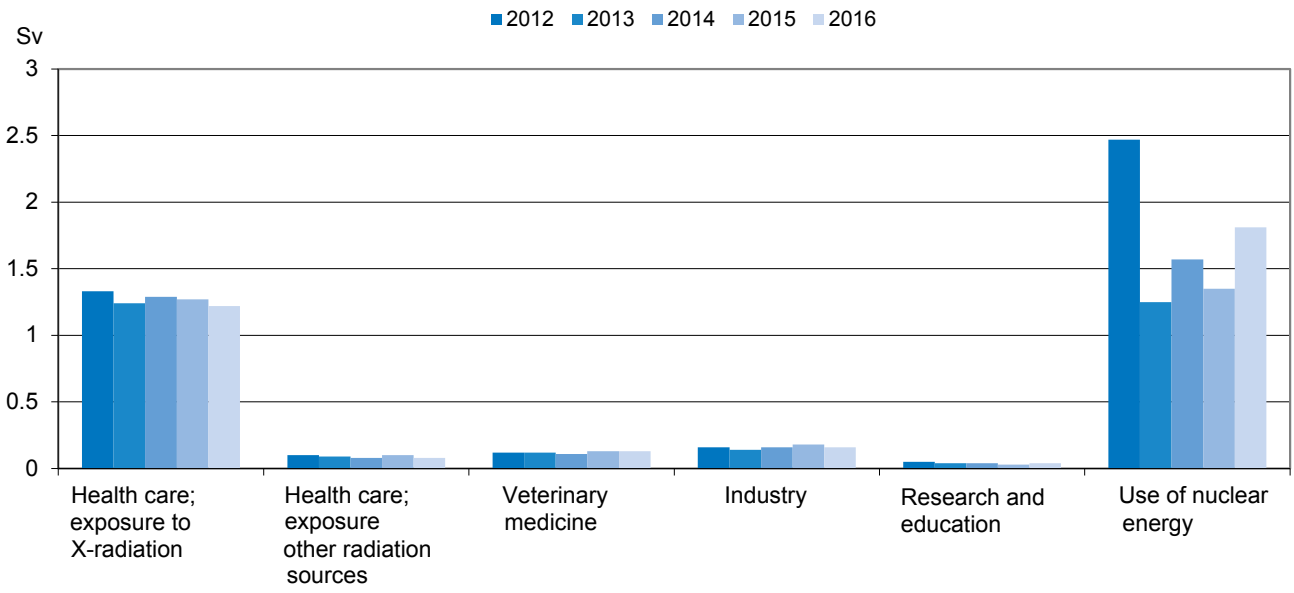

Figure 1. Combined doses ($H_p(10)$) of workers subject to individual monitoring by occupational category, 2012–2016. $H_p(10)$ values are generally (sufficiently accurate) approximations of the effective dose. An exception to this is the use of X-rays in health care and veterinary practices, in which workers use personal protective shields and the dose is measured by a dosemeter on the exposed side of the shield. The effective dose is then obtained by dividing the $H_p(10)$ value by a factor between 10 and 60. In addition to the occupational categories specified in the graph, a few people subject to individual monitoring work in the following fields: manufacturing of radioactive materials, installation/servicing/technical test operation, trade/import/export and services pertaining to the use of radiation and radioactive materials (see Tables 9 and 10 in Appendix 1).

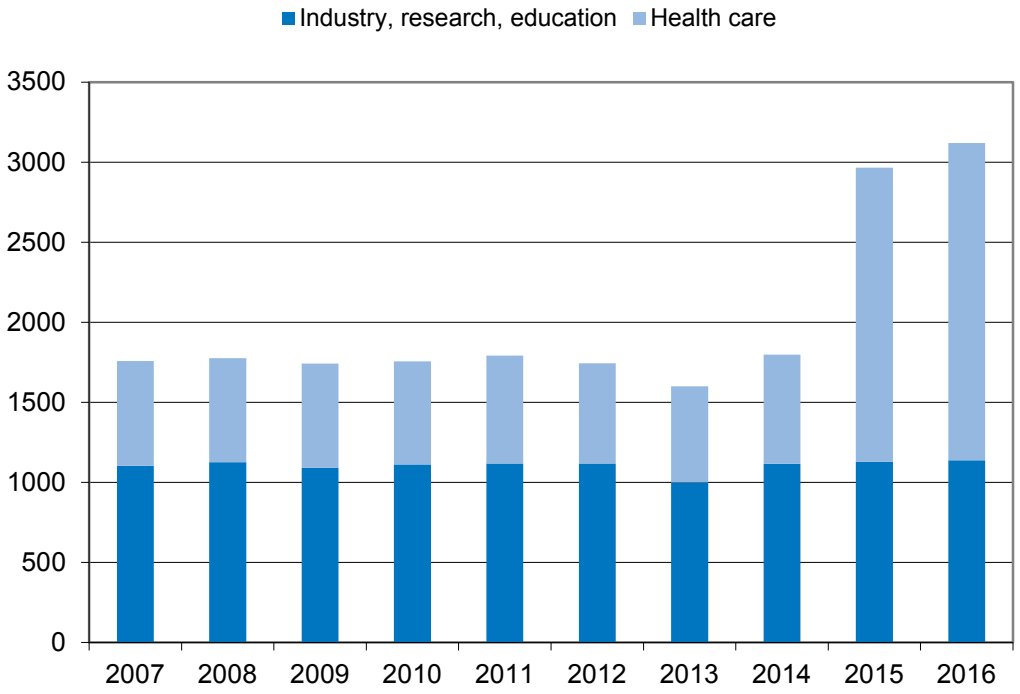

Figure 2. Current safety licences, 2007–2016. The increase in health care licences is due to the dental X-ray operations being changed from registered activities to activities that are subject to a licence.

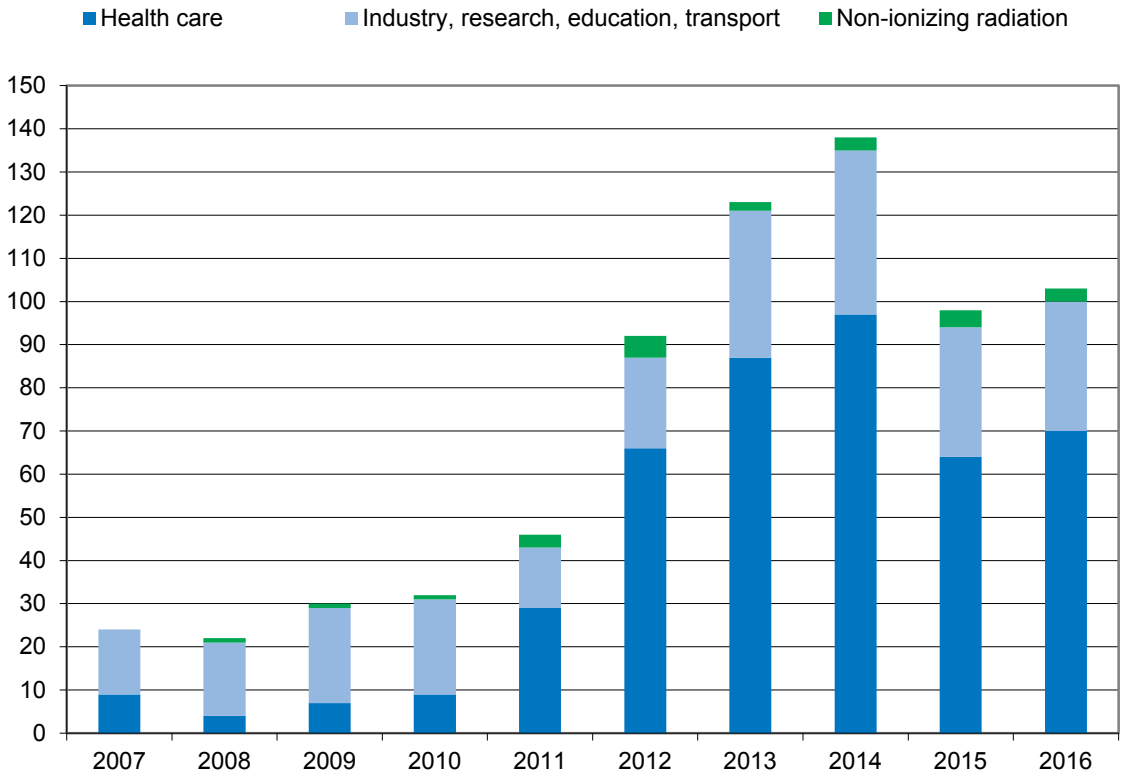

Figure 3. Abnormal events, 2007–2016.

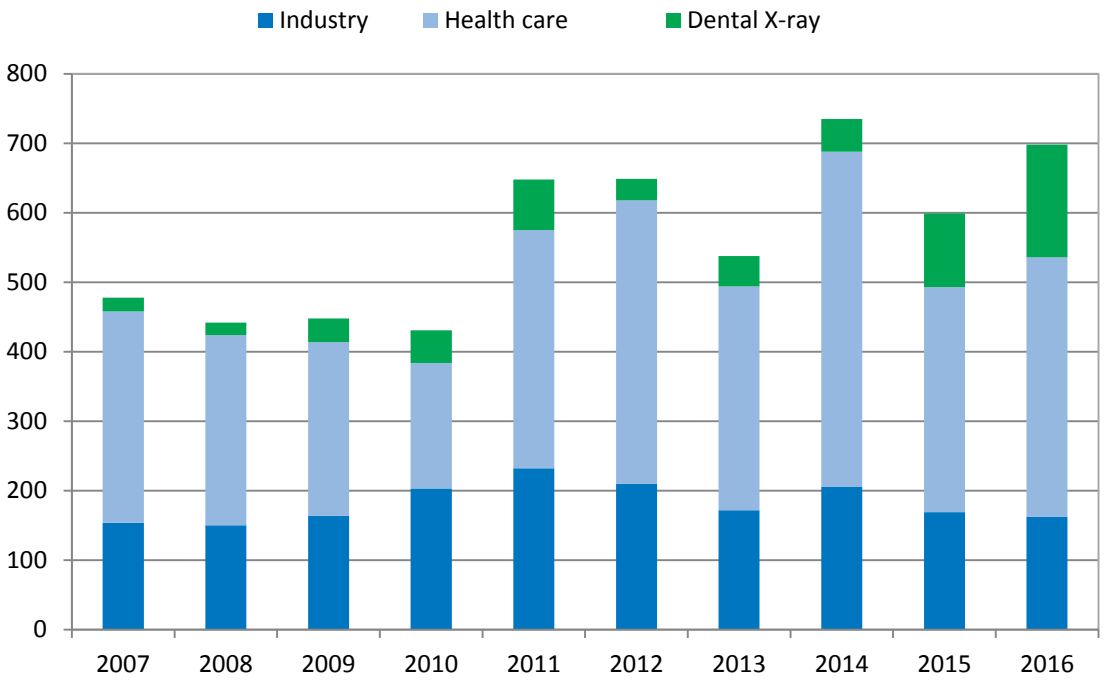

Figure 4. Inspections, 2007–2016.

2 Regulatory control of the use of ionizing radiation

2.1 Use of radiation in health care, dental care and veterinary practices

Safety licences

At the end of 2016, there were 1731 current safety licences for the use of radiation in health care (see also Figure 2) and 252 licences concerning veterinary practices. A total of 1056 licensing decisions (new licences, amendments to existing licenses and terminations of licences) were issued during the year. Table 1 of Appendix 1 shows the numerical distribution of the radiation practices referred to in these licences.

On 1 September 2014, conventional dental X-ray imaging became subject to a safety licence and the issuing of safety licences to these practitioners began. Currently, there are approximately 1600 dental X-ray practitioners.

The average time for processing a safety licence application for X-ray practices in health care was 11.7 days. About six per cent of all licence applications were processed as urgent applications.

Radiation appliances, sources and laboratories

Table 2 in Appendix 1 shows details of radiation sources and appliances, and of radionuclide laboratories used in health care and veterinary practices at the end of 2016.

X-ray practices, dental X-ray practices and veterinary practices

In 2016, STUK set new diagnostic reference levels for patients' radiation exposure in dental cone beam computed tomography (CBCT), as well as cardiological examinations and procedures. In both decisions, reference levels were specified for some completely new examinations and procedures.

STUK published a guide on the optimization of CT scans in nuclear medicine. The guide was written in multiprofessional collaboration with radiologists, medical physicists and nuclear medicine specialists.

The model for the regulatory control of parties running a radiation practice (hereinafter the responsible party) administering radioactive iodine treatment to animals was improved.

STUK used procedures routinelly developed through the EMRP project in the regulatory control of novel radiotherapy accelerators and radiotherapy methods (FFF, or flattening filter free technique). The method was developed further to reduce measurement-technical uncertainties.

STUK arranged the Radiotherapy Physicists' Conference and participated in the arranging of the Radiation Safety Conference. The Radiotherapy Physicists' Conference discussed the quality assurance of appliances, acceptability requirements and the reporting of abnormal events.

During inspections of X-ray practices in health care, STUK recorded doses exceeding reference levels on three different appliances. As a result of these, STUK issued repair orders for the inspected sites, requesting the responsible party to investigate whether a sufficient image quality could be achieved with a lower dose. In addition, the responsible parties were required to make the necessary amendments to their imaging practices. In addition to these, in connection with regulatory control, STUK recorded doses exceeding the reference level on 12 dental panoramic tomography appliances and 32 intraoral X-ray appliances. The reference levels for dental intraoral imaging were updated in 2014, which can still be seen in 2016 as increased occurrence of exceeded reference levels.

STUK compiled and published the report "Number of radiological examinations in Finland in 2015". In 2015, approximately 5.8 million X-ray examinations were carried out in Finland (including dental X-ray examinations). The number of CT scans performed continues to increase. In addition, STUK gathered information on the frequency of nuclear medicine examinations and

radionuclide therapy as well as the activity of radioactive substances administered to patients. The report will be published in 2017.

STUK was preparing a guide on the safe use of radiation in cardiology in collaboration with the Finnish Cardiac Society and experts specializing in the use of radiation in cardiology. The guide will be completed and published in 2017 in the Advice from STUK series.

STUK participated in the Kvarkki project for the implementation of national architecture in radiological imaging (the project for imaging material archiving run by the National Institute for Health and Welfare and KELA) by issuing statements and providing consulting with project plans. At the same time, specification of the characteristics necessary for the automatic collection of patients' radiation exposure data, included in the implementation of Kvarkki, was prepared, and efforts were made to include testing of the processing of patients' radiation exposure data in the testing of the archiving of imaging materials. However, the processing of radiation exposure data was postponed to the second phase of the project, which will be launched in autumn 2017 and in which STUK participates as a member of the project team.

The comparative measurements carried out by STUK during inspections of radiotherapy practices did not reveal any overdoses that would compromise the safety of treatment or any doses not meeting the acceptance criteria. The average difference between measurement results was 0.05% in photon beams and 0.30% in electron beams.

STUK participated in the theme week organized by HERCA (Heads of the European Radiological Protection Competent Authorities), during which inspections were carried out with particular focus on the justification assessment of the use of radiation. This issue was presented at the Radiation Safety Conference in autumn 2016, and STUK will publish a summary of the observations in 2017.

STUK participated in the work of a Nordic Group of Medical Applications (NGMA) relating to the use of radiation in health care. As a result, a joint communiqué was issued on the assessment of the justification of novel health care technologies.

STUK participated in a project of the European Commission, which prepared the EU's recommendation on radiation exposure reference levels for paediatric radiological examinations and procedures. The guide will be published in the EU's Radiation protection series in 2017.

X-ray equipment suppliers reported the X-ray appliances installed or reinstalled in health care practices in 2016 to STUK. The survey conducted found seven X-ray appliances for which a safety licence had not been applied before starting to use them. In addition, a number of dental X-ray appliances that had not been reported to STUK were found in the survey. In connection with the inspections, STUK became aware of eight health care X-ray appliances without a safety licence. Safety licence applications were submitted for these devices.

In 2016, STUK received 53 reports on abnormal events related to X-ray practices in health care (item 2.8). Incidents with minor significance for safety can be reported in annual summaries. A total of 998 such events were reported.

Nuclear medicine

Similar to the previous year, the inspections concerning nuclear medicine paid particular attention to the performing of contamination measurements at regular intervals and always after work. Hand-and-shoe monitors were recommended for measuring the contamination of workers. Measurements were carried out more frequently than before. Responsible parties reported abnormal events concerning contamination cases.

Transports to and from nuclear medicine units were inspected in collaboration with the Police.

STUK published a guide for the use of CT in nuclear medicine for the optimization of CT scans in nuclear medicine. The guide was prepared in multiprofessional collaboration with radiologists, medical physicists and nuclear medicine specialists.

The Potilas isotooppitutkimuksessa (Patient in nuclear medicine examination) brochure was prepared, answering the most common questions asked by patients concerning nuclear medicine examinations. The brochure was prepared in collaboration with doctors, medical physicists and radiochemists from Helsinki and Uusimaa Hospital District and the Finnish Society of Nuclear Medicine. The brochure will be distributed

to patients coming for nuclear medicine examinations.

STUK studied nuclear medicine examinations performed and treatments administered in Finland in 2015 by sending a survey to all hospitals providing these examinations and treatments. The last data for the survey were received early in 2017. Altogether, 45 120 nuclear medicine examinations were performed in 2015. Of these, 1170 were performed on children and 939 were scientific examinations. Compared with the previous survey in 2012, the number of nuclear medicine examinations increased by 10.3 per cent. Radionuclide therapy was administered 2108 times, an increase of 13.7 per cent.

PET examinations increased considerably, by 50.2 per cent compared with 2012, totalling 9545.

In 2015, there were 50 appliances in use for nuclear medicine scanning. Of these, 14 were PET, PET-CT or PET-MRI devices. Altogether 46 appliances were SPECT or SPECT-CT devices or gamma cameras.

The report of the survey will be published in spring 2017.

Radiotherapy

Radiotherapy was provided at all five university hospitals, seven central hospitals and one private clinic to approximately 16 000 patients. In 2016, STUK conducted seven commissioning inspections and 46 periodic inspections of radiotherapy equipment.

The comparative measurements between STUK and hospitals revealed that the treatment dose accuracy at hospitals was very good: the average difference was 0.1% in photon beams (standard deviation 0.4%), 0.3% in electron beams (standard deviation 0.5%) and 0.5% in afterloading sources (standard deviation 1.5%). The comparative measurements did not reveal any dose deviations that would compromise the safety of treatment.

When monitoring the accuracy of the patient dose in radiotherapy, the multi-field plans calculated using the dose calculation system were compared with the corresponding measurement results. Inspections of dose calculation systems that affect patient doses were conducted on more than 600 radiotherapy beams. The calculation accuracy of the dose planning programmes of hospitals and the accuracy of the input data can be considered as very good. Only one deviation of over three per cent was observed.

Towards the end of 2016, Helsinki University Central Hospital announced that it will start building a boron neutron capture therapy station and submitted a request to STUK for an advance statement on shielding and safety arrangements. The device will be installed in 2018 and used for the administration of treatments similar to those administrated using the FIR-1 reactor in Otaniemi, Espoo. However, a nuclear reactor will not be needed to produce radiation; neutrons are produced in a particle accelerator.

2.2 Use of radiation in industry, research and education

The use of radiation in industry, research and education also includes its use in services, installation and maintenance work, the sale and manufacture of radioactive materials, and the transport of radioactive materials.

STUK issued a statement related to radiation shielding to HUS, concerning the planned cyclotron.

In 2016, Finnish Customs prepared the transfer of its train X-ray scanners to Vainikkala. STUK issued statements on the matter and prepared the licensing decision. The commissioning inspection was performed in December 2016.

STUK ensured that companies that are vendors of X-ray equipment have a safety licence by virtue of STUK's decision made in 2016.

VTT Technical Research Centre of Finland is building new facilities. This involves cleaning and decommissioning the old contaminated facilities, as well as obtaining licences for the new facilities in accordance with the Radiation Act. STUK made preparations for regulatory control of these activities by engaging in closer internal co-operation and reviewing the radiation safety requirements with VTT.

In accordance with its plan, STUK inspects transportable radiation sources, as well as their use and transport arrangements, every five years. The inspection interval has been extended from three to five years with a risk-based approach. In connection with the inspections, repair orders were issued on any detected shortcomings in transport arrangements, and their implementation was controlled.

No applications concerning transport of radioactive materials were submitted to STUK for processing in 2016.

STUK strengthened its co-operation with the other regulatory authorities responsible for monitoring the transport of dangerous goods by participating in the meetings of a group coordinated by Finnish Transport Safety Agency (Trafi) and by participating in a joint inspection. In addition, a joint inspection was carried out together with the Police, concerning transport of radioactive substances used for medical purposes. The inspection revealed several shortcomings.

A contamination incident occurred on the premises of Finland's only recognized installation in March 2016. Work areas were contaminated so that they had to be cleaned. Some of the cleaning operations continued into 2017. The processing and final disposal of the contaminated goods and the radioactive waste resulting from the cleaning are still being investigated.

After the incident, STUK imposed a prohibition of activities on the company, so that it will not be able to receive more radiation sources, until it meets the revised more detailed safety criteria. Therefore, currently there is no organization in Finland that can accept radioactive waste. The discontinued reception of waste has led to a situation in which decommissioned radiation sources are left sitting in the warehouses of operators and importers.

On STUK's request, the Safety Investigation Authority started investigating the matter, and its report was published in March 2017. The report can be found at www.otkes.fi

STUK issued radiation shielding-related statements on new particle accelerators for isotope production, and on projects concerning such accelerators.

A report on the radiation safety of the accelerators in research and isotope production was published in 2016, and the proposals included in the report are used for specifying detailed requirements for accelerators. A letter informing about the publication was sent to the responsible parties.

Safety licences

At the end of 2016, there were 1137 current safety licences for the use of radiation in industry, research and education (see also Figure 2). A total of 497 licensing decisions (new licences, amendments to existing licenses and terminations of licences) were issued during the year. The average time for processing a safety licence application was 16.8 days. Table 3 of Appendix 1 shows the numerical distribution of the radiation practices referred to in these licences.

Radiation appliances, sources and laboratories

Figure 5 shows the number of appliances containing radioactive materials used in industry, research and education in the last ten years. The number has remained nearly unchanged for a long time.

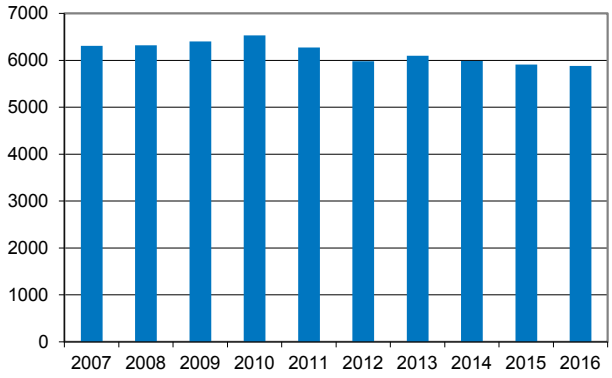

Figure 5. Appliances containing radioactive materials, 2007–2016.

Figure 6 shows the number of X-ray appliances in the last ten years. The number has almost doubled in ten years. Appliances containing radioactive substance have, to some extent, been replaced by X-ray appliances, in addition to which new scanning and analysis device applications have been introduced

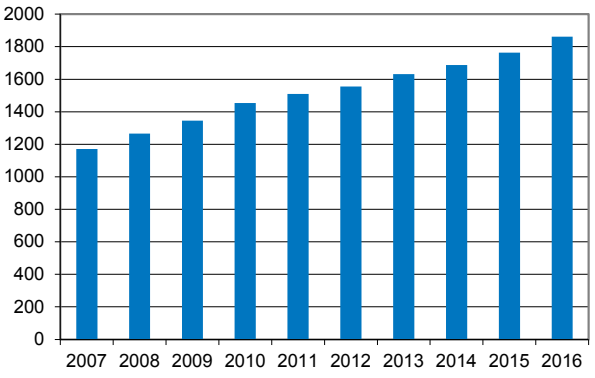

Figure 6. X-ray appliances, 2007–2016.

Table 4 in Appendix 1 shows details of the numbers of radiation appliances and sources, and of radionuclide laboratories used in industry, research and education at the end of 2016.

Table 5 in Appendix 1 shows details of radionuclides used in sealed sources.

X-ray appliance survey

At the beginning of 2017, STUK requested reports from all vendors of X-ray equipment operating in Finland (31 vendors) on appliances delivered in 2016 and their holders. On the basis of the delivery information, it was found that seven responsible parties did not have a licence for the operation or possession of X-ray appliances. In addition, it was found that nine licence holders had not reported their new X-ray appliances to STUK. STUK issued the necessary orders to rectify the shortcomings discovered and controlled that safety licence applications for the use of all the aforementioned devices were submitted or that the devices were appropriately incorporated into an existing safety licence.

2.3 Inspections of licensed radiation practices

Health care, dental care and veterinary practices

In 2016, a total of 536 inspections were conducted on the use of radiation in health care and veterinary practices. STUK conducted 43 inspections of veterinary X-ray practices. These inspections resulted in 372 repair orders issued to the responsible parties. Eight appliances were found that did not have the required safety licence for their use. In addition to this, a few cases of inadequate radiation shielding in imaging rooms (typically the door frame) were detected in the inspections. Three doses exceeding the reference level were measured.

Approximately 1600 responsible parties were engaged in dental X-ray practices in 2016. Patient radiation exposure from dental X-ray imaging was measured in 1000 intraoral X-ray appliances using testing equipment sent by post. The average dose was 1.2 mGy. The dose refers to the dose on the surface of the cheek (Entrance Surface Dose, ESD) when imaging a tooth. The reference level of 2.5 mGy was exceeded in 32 appliances. The reference levels for dental examinations were updated in 2014, which is why the reference level was exceeded more frequently than in previous years.

In addition to this, STUK conducted on-site inspections of 162 panoramic tomography appliances used in conventional dental X-ray practices. Most of the deficiencies observed in these inspections were related to quality control, the appliance itself, its auxiliary instruments or accessories, or the accuracy of the registration information. Doses exceeding reference levels were detected in 12 panoramic tomography appliances.

After the inspections, a feedback survey was sent to the respective radiation safety officers, asking for their opinion on the inspections. Most of the respondents found that the inspections were useful and the issued repair orders were justified. Some respondents wished that inspections could be booked further in advance. Respondents were satisfied with the content and prompt preparation of the inspection reports.

Industry, research and education

Inspections in 2016

In 2016, a total of 162 inspections were conducted at sites where radiation is used in industry, research or education. In addition to these, 16 document reviews were performed. In accordance with the annual plan, periodic inspections are performed every 2–8 years, depending on the category and extent of operations. In addition to this, radiation practices pertaining to new safety licences are inspected before operations are commenced or within a year of issuing the licence. In 2016, nearly all new licences were inspected within a year of issuing the licence. Some of the licences were not inspected for timetable-related reasons or because the licence holder was not active in 2016. The date of inspection is normally agreed on in advance with the radiation safety officer.

After the inspections, a feedback survey was sent to the respective radiation safety officers, asking for their opinion on the inspections. Most of the respondents found that the inspections were useful and the issued repair orders were justified. Respondents were particularly satisfied with the post-inspection review that focused on the findings and the orders issued on the basis of them. In

some cases, radiation safety officers reported that the inspection report took too long to arrive after the inspection. Feedback on the inspections and the professional expertise of the inspectors was generally positive.

Analysis of inspections carried out in 2016

At the beginning of 2017, STUK prepared an analysis of the inspections carried out in 2016. The purpose was to determine the types of observations made during the inspections and how they were divided among the inspected responsible parties. A further goal was to find out which safety deviations are the most common.

On-site inspections of radiation use revealed a total of 414 safety deviations, for which repair orders were issued. Deviations were found in 125 inspections (77% of the inspected responsible parties). No safety deviations were detected in 23% of the inspections. In 2016, significant defects were recorded in three inspections. In addition, good practices were identified in four inspections.

Most of the deviations found concerned deficiencies in the radiation sources used by the responsible parties (a total of 96 findings). Most of these deficiencies concerned inadequate warning labels (34 findings). Unlike the previous analysis, observations were not recorded radiation source-specifically. This means that in an inspection, an observation of a particular type that concerned more than one appliance was recorded only once. Shortcomings in finger guards were found in 12 inspections. Unnecessary radiation sources at the place of use or in storage were found in eight inspections. Lack of training or instructions was detected in 120 inspections. Of these, 44 findings were related to instructions for abnormal events, 24 to instructions of use, and 14 to lacking supplementary training of the radiation safety officer. Inspection findings concerning the radiation safety officer were made in 64 inspections. Of these, 54 safety deviations concerned the inadequate specification of the radiation safety officer's duties.

2.4 Manufacture, import and export of radioactive materials

Details of deliveries of radioactive materials to and from Finland and the manufacture of such materials in Finland in 2016 are shown in Tables 6 and 7 of Appendix 1. The figures in the tables are based on data gathered from holders of safety licences who are engaged in trade, import, export or manufacture.

The tables do not include the following information:

- Radioactive materials procured by responsible parties for their own use from other countries within the European Union, and consigned from said use to other European Union countries.
- Radioactive materials delivered to other countries via Finland.
- Sealed sources with equal or lower activity than the exemption value.
- Smoke detectors and fire alarm system ion detectors containing americium (Am-241). Approximately 50 800 of these devices were imported with a combined activity of about 1.6 GBq. Approximately 250 smoke detectors with a combined activity of about 1.0 Mbq were exported from Finland.
- Lamps and fuses containing radioactive substances imported to Finland. Some special lamps and fuses contain small quantities of tritium (H-3), krypton (Kr-85) or thorium (Th-232).
- Unsealed radioactive sources imported to Finland and exported from Finland. On the basis of activity, the most common unsealed sources imported were Mo-99, I-131, I-123, Fe-55, Lu-177, Br-82, Co-60, P-32, Cr-51, F-18, Tl-201 and Mn-54.

2.5 Radiation doses to workers

A total of 10 951 workers engaged in radiation work were subject to individual monitoring in 2016. Including doses below the recording level, a total of 70 081 dose records were entered in the Dose Register maintained by STUK. This figure includes the dose records of workers exposed to natural radiation – radon and cosmic radiation.

In 2016, there were no cases of the effective dose to a worker exceeding the annual dose limit of 50 mSv or the five-year dose limit of 100 mSv set for workers. The average occupational doses were of the same magnitude as in previous years. The combined doses ($H_p(10)$) to workers were approximately 1.65 Sv in the use of radiation and approximately 1.81 Sv in the use of nuclear energy. The total dose in the use of radiation decreased by 4.4 per cent compared with the previous year.

In the use of nuclear energy, the total dose was 34.2 per cent higher than the previous year. The total dose in the use of nuclear energy varies considerably from year to year, depending on the duration of annual nuclear power plant servicing and the type of the servicing tasks at these facilities. The highest individual dose resulting from radiation work at Finnish nuclear power plants was 10.7 mSv. The highest individual dose accumulated over the last five years (2012–2016) was 38.7 mSv, resulting from working at the Loviisa plant.

In the health care sector, the highest $H_p(10)$ dose (24.9 mSv) was recorded for an interventional radiologist. The highest $H_p(10)$ dose in veterinary practice (6.5 mSv) was recorded for a veterinarian. These correspond to effective doses of approximately 0.8 and 0.2 mSv, respectively. The highest $H_p(10)$ dose in health care from a source other than X-radiation (3.0 mSv) was recorded for a radiographer. In industry, the highest $H_p(10)$ dose (7.9 mSv) was recorded for an individual performing tracer tests. In research, the individual exposed to the highest $H_p(10)$ dose, 4.7 mSv, used different types of sources. In the production and conditioning of radioisotopes, the highest $H_p(10)$ dose was 11.8 mSv.

In some work tasks, such as the handling of unsealed sources, workers are exposed to radiation unevenly. In such cases, the dose to the hands, for example, may be considerably high, even when the effective dose is relatively low. A specific annual dose limit, 500 mSv has been specified for skin, and workers use a so-called finger dosemeter to monitor radiation doses to the hands. In 2016, the dose to the hands did not exceed the annual dose limit for any worker. The highest annual dose was 203.2 mSv, measured for a researcher. In health care and industry, the highest doses to the hands have decreased from the previous year, while in research and the production and conditioning of radioisotopes the doses have increased. The number of workers using finger dosemeters has also increased slightly compared with the previous year. The dose to the hands was below 100 mSv for nearly all workers handling unsealed sources.

Radon at workplaces

Dose information of workers exposed to natural radiation at work is also recorded in the Dose Register, even though such workers are not classified as actual radiation workers.

In 2016, five responsible parties were under an obligation to organize radon exposure monitoring at the workplace (including subcontractors' workers). Altogether 26 workers were subject to radon exposure monitoring during the year, and their doses were recorded in the Dose Register. However, one employer (with five employees) did not submit all working hours for 2016 to STUK, despite the orders issued by STUK.

At the end of the year, only two responsible parties were subject to radon exposure monitoring. At two sites, successful radon mitigation measures were carried out, while one workplace limited the length of stay in the working area. In 2016, the monitoring of 11 workers ended, because radon exposure at the workplace decreased below the action level.

The distribution of the estimated effective doses at the workplaces included in the exposure monitoring is presented in Figure 7. The average effective dose to the monitored workers was 2.8 mSv, while the median was 1.8 mSv. The highest effective dose was 16.9 mSv. The data of five workers are missing.

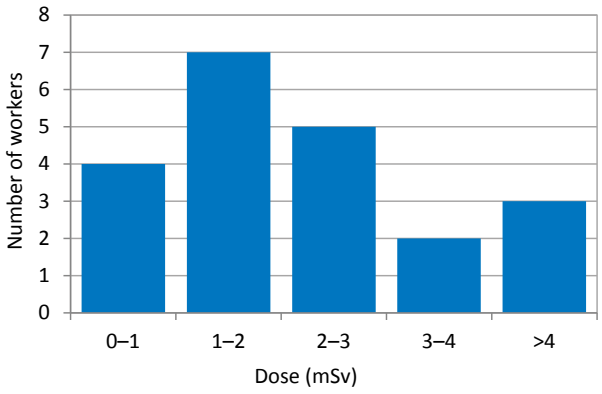

Figure 7. Distribution of the estimated effective doses at the workplaces included in exposure monitoring due to high radon concentration in 2016.

Cosmic radiation

The doses to the workers of four airlines were entered in STUK's dose register in 2016. The 6 mSv limiting value for the effective dose, stipulated in Guide ST 12.4, was not exceeded for any worker. The highest individual annual doses recorded were 5.1 mSv for cockpit personnel and 5.4 mSv for cabin crew. The average annual doses were 2.6 mSv to cockpit personnel and 2.9 mSv to cabin crew. The average doses from 2012 to 2016 are presented in Figure 8.

The total number of workers in flight crews was nearly at the previous year's level. However, the collective dose to the workers increased by 18.9 per cent from the previous year, which also manifests as higher average doses compared with the previous years. Table 8 of Appendix 1 shows the number of workers subject to individual monitoring of radiation exposure and the total doses to them.

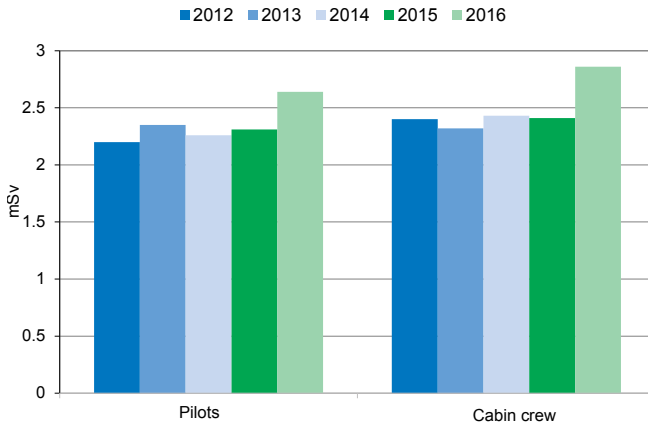

Figure 8. Average doses to flight crews, 2012–2016.

Table 9 of Appendix 1 shows the number of radiation workers subject to individual monitoring over the last five years by field of activity. The combined doses to workers by field of activity are shown in Figure 1 (item 1.1) and in Table 10 in Appendix 1. Table 11 in Appendix 1 shows the doses in 2016 to workers subject to high levels of exposure and to large worker groups.

2.6 Approval decisions and verification of competence

Training organizations providing radiation protection training for radiation safety officers

In Guide ST 1.8, STUK stipulates the minimum qualifications of the radiation safety officers who are responsible for the safe use of radiation. Training organizations that arrange training and competence exams for radiation safety officers must apply to STUK for approval to arrange such exams.

In 2016, approval decisions to arrange exams and training for radiation safety officers were issued to five training organizations. A total of 17 training organizations held valid approval decisions at the end of 2016. The approved training organizations are listed on STUK's website (www.stuk.fi).

Practitioners responsible for medical surveillance

STUK accredits the competence of medical practitioners responsible for medical surveillance of category A radiation workers. By the end of 2016, STUK had accredited a total of 473 doctors as medical practitioners responsible for medical surveillance. Of these, 24 were accredited in 2016.

Parties engaged in aviation operations

In 2016, STUK inspected one airline. The inspection involved reviewing the company's radiation safety procedures and issuing the necessary orders to change the practices in the event they were found non-compliant.

Approval decisions of dosimetric services and measurement methods

STUK approved one dosimetric service and its measurement methods. The approval was issued for operating as a dosimetric service provider conducting individual monitoring measurements on radiation workers. In addition, STUK approved the radiation protection procedures of three airlines, including their dose assessment methods.

Approval decisions of radon measuring equipment

One new approval decision for a radon measurement method was issued in 2016. A list of organizations with measuring methods that have been approved in accordance with the requirements of Guide ST 1.9 is found on the STUK website. It includes the organizations that have consented to their names being published. A condition for approval is that the measuring instrument is properly calibrated.

2.7 Radioactive waste

STUK maintains a national storage facility for low-level radioactive waste. The amounts of the most significant types of waste kept in the storage facility at the end of 2016 are shown in Table 12 of Appendix 1.

2.8 Abnormal events

Pursuant to section 17 of the Radiation Decree (1512/1991), any abnormal event pertaining to the use of radiation that is substantially detrimental to safety at the place where the radiation is used or in its environs must be reported to STUK without delay. Similarly, any disappearance, theft or other loss of a radiation source such that it ceases to be in the possession of the licensee must be reported. Any other abnormal observation or information of essential significance for the radiation safety of workers, other people or the environment must also be reported.

A total of 102 abnormal events of the use of ionizing radiation were reported to STUK in 2016 (some of the abnormal events that occurred in 2016 were not reported to STUK until early 2017). Of these reports, 70 concerned the use of radiation in health care and 30 the use of radiation in industry or the use of orphan sources. Two abnormal events were reported in veterinary practices. The numbers of abnormal events that occurred in Finland in 2007–2016 are shown in Figure 3 (item 1.1), including abnormal events in the use of non-ionizing radiation, which are described in more detail in item 4.4.

Abnormal events in X-ray practices in health care that are of minor significance for safety and do not require immediate reporting may be compiled and reported together annually. An annual notification differs from immediate reports in that annual notifications only list the number of abnormal events under each respective event category. Notifications on the year 2016 were received from 46 parties, reporting a total of 998 abnormal events. The numbers of abnormal events reported in annual notifications are shown by category in Table 1 below.

The abnormal events in the use of ionizing radiation are presented below, grouped by the use of radiation. More details are given of typical or significant events.

Abnormal events in health care

Abnormal events in X-ray practices

In health care X-ray practices, 53 abnormal events were reported immediately, compared with 35 events in 2015. In addition, 10 abnormal events were reported on compiled annual notifications that should have been reported immediately. The most common reason for an abnormal event in 2016 was equipment or system failure (14 cases), while the second most common reason was a human error during an examination (10 cases). They accounted for 26 and 19 per cent, respectively, of immediately reported abnormal events. Many of the abnormal events were related to failed use of contrast medium during imaging. For example, the contrast medium hose had come loose in the middle of imaging, or the injecting of the medium was incorrectly timed. The highest radiation exposure to a patient was 24 mSv, caused by an unnecessary abdominal CT-scan. In this case, a dramatic drop in the patient's haemoglobin was detected on the day following a procedure. This is why an abdominal CT scan was performed on the patient. Later, it turned out that the drop in the haemoglobin value was due to incorrect sample collection. The sample was incorrectly collected from a hand in which the patient had an IV drip. The highest individual exposure to a foetus was 9 mSv. In addition, two abnormal events were reported concerning veterinary x-ray practices.

Example event 1:

A foetus was inadvertently exposed to radiation when a CT-scan of the head, cervical spine and abdomen and a chest X-ray were performed on a patient in accordance with the trauma protocol before the result of a pregnancy test was available. The pregnancy test carried out later was positive. The radiographer knew the result of the renal function test before the result of the pregnancy test. The patient said twice that she is not pregnant when the personnel asked her about pregnancy. The patient had incorrect information, and the result of the pregnancy test was not available before the CT scan. Practically the entire dose to the foetus came from the abdominal CT scan. Over the uterus, the CTDI was 11.3 mGy. Of this, the dose to the foetus was estimated to be approximately 9 mGy.

Table 1. Abnormal events in health care reported through annual notification.

Exposed party	Type of abnormal event	Cause or contributing factor	Number of events per year
Abnormal events related to the referral			
Wrong patient	Referral written for the wrong person	Human error	**21**
		Human error, the high likelihood of errors in the referral system*) a contributing factor	**3**
Patient	Incorrect examination or anatomical object in the referral	Human error	**252**
		Human error, the high likelihood of errors in the referral system*) a contributing factor	**31**
	Another type of error in the referral		**140**
Abnormal events related to the performance of the examination			
Wrong patient	Wrong patient examined	The patient's identity was not verified before the examination	**21**
Patient	An incorrect examination was performed or an incorrect anatomical object was imaged	Human error during the performance of the examination	**55**
	Failed examination or an excess exposure related to the examination	Erroneous or deficient instructions	**11**
		Human error during the performance of the examination	**131**
Extraordinary exposure, other events			
Patient	Failed examination or an excess exposure related to the examination	Isolated case of equipment failure	**156**
		The high likelihood of errors in equipment, an auxiliary appliance or system*) as a contributing factor	**105**
	Examination repeated unnecessarily	No information available on earlier similar examination, or results from earlier examination not available	**21**
Patient and worker	Worker also exposed due to the abnormal event mentioned above (when the worker's exposure is not significant)		**8**
Worker	Worker exposure (when the exposure is not significant)		**11**
	Other event:		**6**
Unintended exposure of the foetus			
Foetus	Pregnant person exposed	The pregnancy is at such an early stage that it cannot be verified	**2**
		The possibility of a pregnancy was not considered before the procedure	**1**
A near miss that caused actions to be taken at the place of radiation use			
	When a more detailed report to the authorities is not considered purposeful		**23**

*) A high likelihood of errors refers to the poor usability of equipment or a system, allowing extraordinary radiation exposure to be caused by a human error that can occur easily.

Example event 2:
In dose survey, the patient dose of a chest X-ray was higher in the PA direction than in the LAT direction, which is not typical. The total dose was approximately 70 per cent of the reference level. According to the supplier's maintenance service, the ionizing chambers of the equipment had been connected wrong. Even though the upper lateral chambers had been correctly chosen for the imaging, the lower lateral chambers were in use. This error has affected all examinations that use lateral chambers, but in other than chest X-rays (such as the pelvis or abdomen), the effect has been smaller on the basis of dose survey. Presumably the coupling had been incorrect since the installation of the appliance. In chest X-rays, the dose in the PA direction has been approximately double compared with a situation in which the chambers function correctly. The extra dose has been approximately 0.015 mSv per imaging. Approximately 2000 chest X-rays have been taken each year.

Example event 3:
A CT scan of the head was performed on a patient, whose referral was two years old. The patient registered in the office and was recorded to have arrived on an old referral instead of the referral issued on the same day. The purpose was to perform a chest X-ray on the patient. The nurse who received the patient for the examination had seen that the patient had registered. When the patient's status is "registered", the RIS software does not show the date of the referral; it only shows the date and time when the patient was recorded as registered. Other similar near-miss situations have occurred. The unnecessary CT scan caused an estimated dose of 1.3 mSv.

In addition to the 16 categories specified in advance (see Guide ST 3.3), the 998 events reported in annual notifications were divided into other events with minor significance in terms of radiation safety and into undefined near-misses. Additional information was reported for some events. Of the reported events, 45 per cent concerned errors in the referral. It is estimated that this category also included near-misses, that is, incorrect referrals that were noticed before they led to imaging errors. Individual equipment failures were reported in 156 cases. Imaging of wrong patient was reported 56 times, and a foetus was inadvertently exposed to radiation in three cases. This was the second year when annual notifications were collected. Their number increased from the 755 events in 2015.

Abnormal events in nuclear medicine units

Nuclear medicine units in the health care sector reported 13 abnormal events. The number of reported abnormal events has fallen considerably compared with previous years. In 2014 and 2015 there were 34 and 27 reports, respectively. Approximately half of the reduction is due to a reduction in the number of reports from one large operator.

In five cases, the abnormal event was related to the user's mistake in carrying out an imaging examination. In three cases, the imaging of the patient had to be repeated because of imaging equipment failure. In two cases, a worker or work area was contaminated by a radiopharmaceutical. In eleven cases, the exposed party was the patient, while a worker was exposed in two cases. The highest individual extra exposure caused by an abnormal event was 17 mSv, resulting from performing a PET-CT scan on a patient with incorrect CT imaging parameters.

Example event 1:
In a CT scan performed in connection with a PET examination, the radiographer using the device left a too high tube current in the scanning protocol. The considerably higher than normal imaging parameters were not detected before the imaging started. The too high imaging values caused an extra exposure of 17 mSv to the patient.

Example event 2:
When a nurse was injecting phosphorus 32 treatment to a patient, a few drops of radiopharmaceutical splashed from the cannula. Contamination measurements detected radioactive medicine at several places on the nurse's skin and in the injection room. Following the event, the nurse changed clothes and washed, after which contamination was detected only on the skin of the hands. The dose to the most exposed quadrat centimetre of skin was estimated to be 160 mSv.

Example event 3:
During cardiac perfusion SPECT-CT stress imaging, the patient was wearing a bra, but not

during the rest imaging. Therefore, the breasts were differently positioned in the scans, and non-attenuation-corrected stress and rest images could not be compared with each other, which complicated the interpretation of the examination. The rest imaging was repeated later so that the patient was wearing similar clothes as during the stress imaging. The extra rest imaging caused an exposure of approximately 4.6 mSv to the patient.

Abnormal events in radiotherapy

Four abnormal events were reported in radiotherapy. In the most significant case, there was a systematic alignment error of six millimetres in brachytherapy administered to alleviate biliary pain. The error concerned all patients who had received intrabiliary radiotherapy between 2011 and 2016 at the clinic, altogether 34 patients. The alignment error was due to an adapter that was missing from the treatment device. According to the clinic's assessment, the clinical significance of the alignment error for the treated patients was small, as there is a 2 cm margin in the administration of the treatment.

In one case, the healthy leg of a patient had been positioned incorrectly in leg pain radiotherapy. Because of the incorrect positioning, nine centimetres of the foot of the healthy limb were exposed to a dose of 7 Gy. According to the doctor's assessment, the healthy leg will not suffer any significant harm from the radiation dose.

Two abnormal event reports concerned the starting of a CT scan while the worker was in the imaging room. The workers in the imaging room were exposed to a low amount of scattered radiation.

Abnormal events in industry, research, education and transport

In 2016, STUK received reports of 29 abnormal events concerning the use of radiation in industry, such as radiography or use of unsealed sources, transport of radioactive materials, or detection of radiation sources in a metal recycling process or otherwise.

Use of radiation in industry

Eight abnormal events related to the use of radiation in industry were reported.

In one case, the working condition of an alpha irradiation device used by STUK for research was being inspected, when the surface of the device's plutonium source (Pu-238, 0.93 GBq) was found to be damaged. When the source was being detached, contamination stuck to the fingers of the person performing the work and spread from the fingers to his clothes and the working area. The extent and amount of contamination were measured and found to be relatively low. The necessary cleaning procedures were then carried out and it was ensured that no contamination remained on the person, in the area where the device was handled, or anywhere else. The exposure of the person handling the source was studied by whole body counting and excretion analyses. On the basis of these, it was estimated that the person had received a radiation dose of approximately 4.6 mSv through inhalation. As a result of the event, STUK revised its instructions.

A contamination incident occurred on the premises of Finland's only recognized installation in March 2016. Work areas were contaminated so that they had to be cleaned. Some of the cleaning operations continued into 2017. The processing and final disposal of the contaminated goods and the radioactive waste resulting from the cleaning are still being investigated.

Example event 1:

A person working in a chemical factory was in a silo and the shield of a sealed source, located outside the silo, was not closed. The activity of the sealed source was 3434 MBq and the work lasted for about 15 minutes. According to a conservative estimate, the exposure was approximately 0.2–0.6 mSv.

Example event 2:

Two workers at an industrial plant were exposed to radiation during the cleaning of a tank. The radiation source used for measuring the surface of the tank had not been turned off before the workers went inside the tank. The company's tank work instructions were not followed. The workers received an extra radiation dose of 2.4 µSv at the most. The dose remained low, because the work took only 15 minutes and the workers were not in the radiation beam all the time. As a result of the event, the company revised its tank work permit procedures.

Example event 3:
In one case, a wooden crate left at the waste station had labels indicating transport of dangerous goods (Class 7). The crate was empty, and the Emergency Services Department used a radiation meter to check that the crate did not contain any radioactivity. STUK advised to remove the unnecessary labels.

Industrial radiography

In 2016, STUK received one report of an abnormal event in industrial radiography. The case concerned the warming of an X-ray tube, during which the area had not been sufficiently delimited and a radiation window shutter had not been used. In addition, the X-ray tube was positioned so that outsiders were exposed to an extra dose of radiation. However, the doses remained low, as people were using radiation alarms, which sounded an alarm and the people left the area. The workers were exposed to doses of 2–80 μSv.

Use of unsealed sources

In 2016, seven abnormal events related to unsealed sources in industry, research and education were reported to STUK.

Example event 1:
One of the events concerned incorrect transfer of fluorine-18 activity from the cyclotron to the synthesis device. The event was noticed when the transfer had taken exceptionally long. It turned out that, instead of the hot cell of the production laboratory, the fluorine had ended up in the research laboratory's open, hot cell. Workers were not exposed to immediate danger in the situation, thanks to the radiation monitoring systems. When the monitoring system alarmed of the increased dose rate, the workers immediately left the area and the cumulative dose to them remained low. The event was specified as a quality deviation, and it was processed in accordance with the quality system of the responsible party; reports were submitted to STUK and Valvira. The supplier of the device was also immediately informed about the event, and an explanation of the failure was requested.

Transport of radioactive materials

Four abnormal events related to the transport of radioactive materials were reported to STUK in 2016. In three cases, a package was damaged during transport, and in one case the transport vehicle run off the road. In all cases, the packages or their inner packages remained unbroken.

Disappearance of radiation sources

Two battery-powered X-ray scanners that transmit pulsed X-radiation were stolen from an operator's premises. However, the devices were found and returned to the owner.

Found radiation sources

In 2016, eight events were reported to STUK in which the radiation monitoring meters of a metal recycling company or steel mill detected radioactive material. In two of these cases, a radiation source was found among recycled metal. In one of these two cases, the radiation source (Cs-137, reference activity 19 GBq) was originally from Sweden. The owner of the source was found through a search conducted in co-operation with the Swedish Radiation Safety Authority (SSM) and the source was returned to Sweden. In two cases, a sealed source was found on an operator's premises. In one case, an unlicensed X-ray scanner was found in the estate of someone who had been declared bankrupt.

3 Regulatory control of practices causing exposure to natural radiation

This chapter describes the regulatory control of natural radiation from the ground and related operations.

3.1 Radon at conventional workplaces

The radon measurement season covers the end and beginning of the year, and there is a two- to four-month delay between the ordering of an alpha track radon measurement and the sending of the results. Therefore, the numbers of alpha track radon measurement-related orders and results are different. Radon measurements are carried out by STUK and other parties, and radon concentrations are recorded in STUK's national radon database (RAMI). Workplace radon concentrations measured by other parties that are below 400 Bq/m^3 have not usually been reported to STUK.

Nearly 900 radon concentration-related inspections were carried out (= the number of inspection reports sent). Approximately 850 sites (= workplace or separate building) were inspected, and nearly 3000 radon concentration measurements were recorded in the RAMI database for them. Slightly over 2000 of these were STUK's alpha track radon measurements. Ten radon concentration measurements during working hours were carried out by STUK and 26 by other parties using continuous metering.

The current action level, 400 Bq/m^3, was exceeded in seven per cent of long-term radon concentration measurements at conventional workplaces, and 300 Bq/m^3 was exceeded in ten per cent of the measurements. According to employers' reports, at the end of 2016, over 1000 employees worked in a space where the radon concentration of 400 Bq/m^3 was exceeded. In addition, nearly 1300 employees worked in a space with a radon concentration of over 300 Bq/m^3.

At conventional workplaces, the 400 Bq/m^3 annual average radon concentration during work was exceeded at approximately 15 per cent of the measured workplaces that were reported to STUK (Figure 9). STUK issued orders on additional clarifications or reduction of radon exposure to nearly 130 workplaces for exceeding the action level. At the end of the year, there were still 90 workplaces at which the action level was exceeded. According to employers' reports, at the end of 2016, over a thousand employees worked in a space where the radon concentration of 400 Bq/m^3 was exceeded. STUK controls that radon exposure will be reduced also at these workplaces as soon as possible.

If mitigation measures fail to reduce the radon concentration, radon exposure monitoring will be imposed on the facilities in question. Five responsible parties were under exposure monitoring in 2016. At the end of the year, their number had decreased to two. At two sites, successful radon mitigation measures were carried out, while one workplace limited the length of stay in the working area.

3.2 Radon in underground mines and at excavation sites

Radon exposure in underground mines was inspected in accordance with the specified goals. The basic inspection interval is two years. In addition, all long-term underground excavation sites reported to STUK pursuant to section 29 of the Radiation Decree were inspected. Altogether 28 radon inspections at 18 sites were carried out in mines and at underground excavation sites.

Radon concentration was higher than 400 Bq/m^3 at three excavation and construction sites. STUK issued orders to reduce the radon concentration at these sites. All of the sites succeeded in reducing the radon concentration to below 400 Bq/m^3. In one mine, the radon concentration was higher than 400 Bq/m^3, but the mine was not in operation at the time. An order was issued to carry out a new inspection at the beginning of the next mining period.

3.3 Radioactivity of construction materials

STUK monitors exposure caused by natural radioactive substances contained in construction materials and other materials. The action level for radiation exposure to the population caused by construction materials used for buildings is 1 mSv a year. A total of 76 monitoring measurements were carried out concerning the radioactivity of construction materials intended for building production. These resulted in the preparation of 12 inspection reports that required further reporting. According to the reports submitted to STUK, there were no cases in which the action level was exceeded. Activity measurements of construction materials have increased as a result of the EU Construction Products Regulation, which entered into force on 1 July 2013. The Construction Products Regulation makes the CE marking obligatory, also in Finland, in all construction products that enter the market and fall within the scope of the harmonized product standard. The harmonized product standards are drafted by the European Committee for Standardization CEN.

3.4 Radioactivity of household water

The rules for the regulatory control of household water radioactivity were amended in 2016, and the radioactivity of household water was monitored more extensively and systematically. The dose caused by radioactive substances in household water must not exceed 0.3 mSv a year (dose ingested in food and drink). The radioactivity of household water was measured from the water of approximately 600 water supplies, including waterworks and public premises. In approximately ten locations, radioactivity (mainly radon concentration) exceeded the action level and the responsible party took measures to reduce the radioactivity of drinking water.

3.5 Regulatory control of other natural radiation

STUK has been monitoring the radioactivity of the surroundings of the Talvivaara mine, with regular samples collected three or four times a year. The monitoring has revealed elevated uranium concentration of over 100 micrograms per litre mainly in the mine area's water systems, such as the opencast quarry and Salminen. Concentrations in the surface waters of water systems located outside the mine area are so low that they do not have any radiation protection-related significance for people, animals or the environment. Such low concentrations do not cause any adverse health effects in humans. Currently, there are no radiation-related restrictions on the use of natural products or foods harvested in the area.

In addition to environmental surveillance, STUK has been involved in the preparation of various statements related to mining operations and provided radiation protection guidelines related to natural radiation.

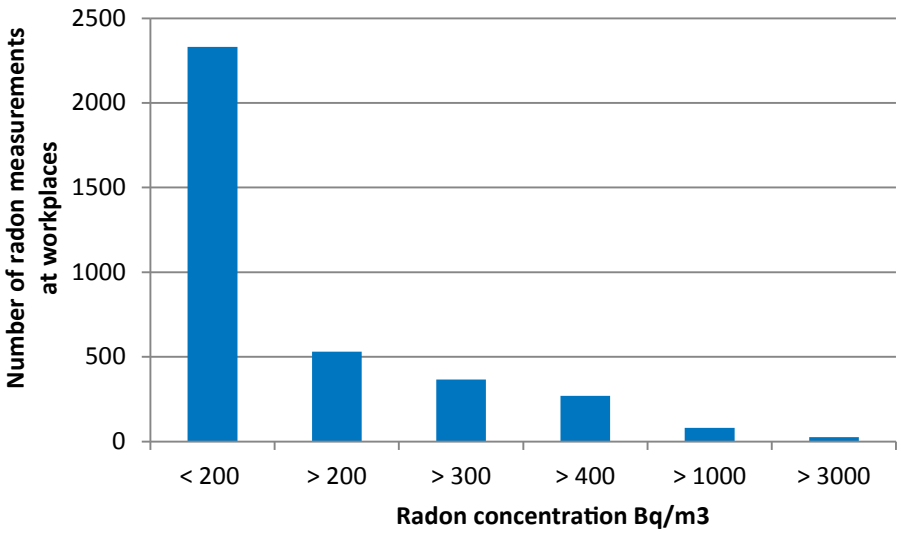

Figure 9. Distribution of the concentrations detected in workplace radon measurements across different concentration levels in 2016.

4 Regulatory control of the use of non-ionizing radiation

4.1 General

"Non-ionizing radiation" refers to ultraviolet radiation, visible light, infrared radiation, radio frequency radiation, and low-frequency and static electric and magnetic fields. Coherent light, or laser radiation, is a special type of visible light. The use of non-ionizing radiation requires a preliminary inspection only in certain special cases, such as the use of high-powered laser equipment in public performances. In other respects, the Non-Ionizing Radiation (NIR) Surveillance Unit of STUK conducts market surveillance of devices and practices that expose the public to non-ionizing radiation. Market surveillance is targeted at the following functions:

- sunbed services
- consumer laser devices
- wireless communication devices and high-powered radio transmitters causing public exposure
- cosmetic treatment devices that utilize non-ionizing radiation and their use in services.

In addition to regulatory control, STUK issues instructions on the application of the recommended values of low-frequency electric and magnetic fields, stipulated by the Ministry of Social Affairs and Health Decree 294/2002, to uses such as power lines, and approves the methods and instructions used in the inspection and regulatory control of the radio and radar devices used by the Finnish Defence Forces.

The work of the NIR Unit in regulatory control of the use of non-ionizing radiation in 2007–2016 is shown in Tables 13–16 of Appendix 1. Some dangerous laser devices have been found, but devices such as laser pointers have been available in the market less frequently than before. In 2016, STUK intervened 18 times in the sale of a dangerous device and once in the unlicensed use of an effect laser. Similar to previous years, STUK received a number of requests for official statements and information requests related to electromagnetic fields from the authorities. In particular, STUK received requests for statements on power line projects.

Enhanced monitoring of the use of non-ionizing radiation was targeted at providers of beauty treatments and sunbed services that use radiation. Many shortcomings were detected that affect safety.

The increased online trade with consumers ordering products directly from outside the EU poses a challenge to the regulatory control of consumer products. In addition, the prices of products such as high-powered laser equipment have decreased considerably as a result of the advancement of technology. In many product categories, traditional branded products are accompanied by cheap non-branded models. STUK monitored the situation actively and noticed a positive development: dangerous laser pointers were found less frequently than before. However, many of the tested mobile phones and tablet computers were found to be non-compliant. Nevertheless, severe safety defects were not detected. The radiation safety and compliance of products sold by traditional stores and Finnish online stores can be estimated to be at a satisfactory level.

In addition to carrying out regulatory control, STUK promotes the reduction of the harmful effects of UV radiation through active communication and participates as an expert in the discussion concerning the health effects of electromagnetic fields. Concerns related to mobile phone base stations and wireless networks have been particularly apparent in citizens' inquiries and information requests to STUK.

4.2 Regulatory control of UV radiation devices

Regulatory control of sunbed devices and facilities is carried out in co-operation with the municipal health protection authorities under the amendment to the Radiation Act that entered into force on 1 July 2012. Health inspectors audit the facilities as part of the regulatory control pursuant to the Health Protection Act and submit a report on their findings to STUK for decision-making. In addition, STUK carries out its own inspections where necessary.

The transition period for the amendment (section 44 of the Radiation Act) that prohibited self-service sunbed facilities ended on 1 July 2015. In 2016, non-compliance with the requirement was still frequently detected and enhanced monitoring was continued. Altogether 55 inspections of sunbed facilities were carried out by municipal health protection authorities. In addition, eight sunbed facilities were supervised on the basis of STUK's own monitoring. Of these, four were inspected on site (Appendix 1, Table 15). In 48 per cent of the supervised facilities, the responsible person required by law was not present during all hours of use of the sunbed equipment. Major technical deficiencies affecting safety were detected in 21 per cent of the facilities, and minor deficiencies were found in 31 per cent. The most common shortcomings were associated with instruction manuals and timers.

4.3 Regulatory control of laser devices

The regulatory control of consumer lasers is divided into market surveillance of traditional and online sales. In addition, the use of high-powered laser equipment in public performances is subject to regulatory control.

In connection with market and on-site surveillance, STUK intervened in the sale or use of 19 laser devices. Of these cases, 18 were related to the selling of a laser device on a website for trade between consumers, and one was related to a device found in the market without the proper labelling. The use of a device was prohibited in a case in which an inspector from STUK noticed an unlicensed high-power laser pointed towards an area open to the public in the Asematunneli area in Helsinki. The shopkeeper who was using the device removed it from use immediately and no damage is known to have resulted from the event.

STUK received 39 notifications on the use of laser equipment in public shows. STUK inspected 11 of these performances on site. In the inspections, the safety arrangements and the pointing of the laser beams were mainly found to comply with the requirements. In one show, STUK had to prohibit the use of the planned effects, as they were considered dangerous on the basis of the plan submitted to STUK. In 2016, more laser shows were arranged in Finland than ever before.

Table 13 of Appendix 1 includes a summary of the laser inspections.

4.4 Regulatory control of devices producing electromagnetic fields

STUK tested 11 products in the market surveillance of wireless communications devices (Table 16 of Appendix 1). The surveillance focused on brands new to the Finnish market. Phones and tablet computers were selected for testing. Similar to the previous year, deficiencies such as insufficient markings were detected. No deficiencies were detected that would affect radiation safety. Non-compliant devices were reported to the Finnish Communications Regulatory Authority.

Mobile phone base stations were monitored through preliminary safety analyses based on reports from citizens. All base stations were found to be safe and installed in a compliant manner.

4.5 Regulatory control of cosmetic NIR applications

An extensive campaign was carried out in 2016 for the regulatory control of companies providing cosmetic treatments. STUK investigated the compliance of operations with 27 responsible parties. In addition, STUK arranged a discussion meeting for responsible parties in this field, informed actively about requirements and developed methods for the safety assessment of equipment. In most of the inspected cases, operations were not compliant with the requirements of the Radiation Act, and the knowledge of the requirements among the companies providing cosmetic treatments was found to be low.

4.6 Other tasks

STUK received a number of requests for statements on power line projects and land use plans near power lines. Altogether seven statements were issued on projects. In 2016, STUK also carried out comprehensive analyses of the electric fields of power lines and the safety of ultrasound.

Two statements were issued on other matters related to non-ionizing radiation. They concerned legislative projects in other administrative branches.

4.7 Abnormal events

In 2016, STUK received three notifications of events caused by *non-ionizing* radiation that required immediate action. In one case, a pupil of a school pointed a high-power laser device at another pupil. The police asked STUK for an assessment of the event. Evidently no eye damage was caused, but according to STUK's assessment, the device was very dangerous. In the second case, a treatment device producing radio frequency radiation was used for a cosmetic treatment and caused a burn to the customer's skin. The investigation of the case is still underway. In the third case, an inspector from STUK noticed an unlicensed high-power laser pointed towards an area open to public in the Asematunneli area in Helsinki. The shopkeeper who was using the device removed it from use immediately and no damage is known to have resulted from the event. Accorcing to STUK's assessment, the lasers of the device would very probably have caused damage if they had hit anyone's eye.

The numbers of abnormal events in 2007–2016 are shown in Figure 3 (item 1.1; see also item 2.9 on abnormal events in the use of ionizing radiation).

5 Regulation work

Radiation safety guides

For the achievement of a standard of safety that complies with the Radiation Act, STUK publishes guides (ST Guides) for responsible parties that use radiation or engage in practices causing exposure to natural radiation. The guides are published in Finnish and translated into Swedish and English.

The following guides were updated and published in 2016:

- ST 1.8 Qualifications and radiation protection training of persons working in a radiation user's organization
- ST 1.9 Radiation practices and radiation measurements
- ST 5.1 Radiation safety of sealed sources and equipment containing them
- ST 5.4 Trade in radiation sources
- ST 6.1 Radiation safety when using unsealed sources.

It has been possible to comment on draft versions of the guides through the extranet service ("ohjeistoextranet") on the STUK website. External users of the service can see each other's comments. Citizens can also use the service to view the ST guides that are being prepared and give feedback on them to STUK.

Other regulation work

The EU's new radiation safety directive (2013/59/Euratom, BSS Directive) was approved on 5 December 2013. It must be implemented in national legislation by 6 February 2018. The Finnish radiation legislation will be comprehensively revised in connection with the implementation. The Ministry of Social Affairs and Health established a steering group to coordinate the implementation of the new radiation safety directive and the comprehensive revision of radiation legislation in January 2015. In March 2015, the Ministry set up subordinate working groups for the processing of specific areas of the directive.

In 2016, STUK prepared drafts of the new Radiation Act sections. They were discussed by the steering group established by the Ministry of Social Affairs and Health to coordinate the preparation of radiation legislation and the implementation of the radiation safety directive, and by the steering group's subordinate working groups, in accordance with STUK's project plan. STUK submitted its proposal for the new Radiation Act to the Ministry of Social Affairs and Health on 9 May 2016. After this, STUK and the Ministry of Social Affairs and Health together prepared the government proposal for the new Radiation Act. The Ministry of Social Affairs and Health sent the proposal to external parties for statements for 23 November 2016–15 January 2017. The proposal has also been available for comments by citizens on the website of the Ministry of Social Affairs and Health. The Act will be finalized on the basis of the statements. In addition, the decrees and STUK's regulations to be issued under the Act will be prepared in 2017.

The new Radiation Act and the lower level statutes issued under it implement the requirements of the EU's radiation safety directive concerning ionizing radiation and revise the provisions concerning non-ionizing radiation. The government proposal also involves amendments to a number of associative laws. The key principle of the revision is to concentrate regulatory control more accurately on areas with the highest radiation risks. The new Act will provide a new framework for the safe use of radiation. Those requirements that are significant for society and restrict the rights of individuals will be transferred to the new Act in the manner required by the Constitution. Provisions on less significant matters will be laid down in decrees, and provisions on the authorities' rights to issue regulations will be

exactly and clearly defined.

The comprehensive revision of radiation legislation is an extensive project and requires co-operation between different ministries and the fields they represent. The participants of the revision work include experts from ministries, national boards, labour market organizations, training organizations and responsible parties, more than 100 people altogether.

STUK and the Ministry of Social Affairs and Health together prepared the government proposal for an Act on the recognition of physicians to work as an occupational physician performing the medical surveillance of workers in category A and for some related Acts. The President approved the bill (170/2017) on 24 March 2017 and the Act enters into force on 1 June 2017. The Act implements the requirements of the EU's directive on radiation safety concerning the recognition of the qualification of said physicians and transfers the recognition of physicians from STUK to Valvira as of the effective date of the Act.

6 Research

The objective of STUK's research activities is to produce new information on the occurrence and measuring of radiation, the harmful effects of radiation and their prevention, and the safe and optimal use of radiation sources and radiation use methods. Research supports the regulatory and metrological activities of STUK and the maintenance of emergency preparedness.

A further purpose of research related to the uses of radiation is to increase knowledge and expertise in this field and to ensure reliable measurement of radiation. Research on ionizing radiation is mainly related to medical uses of radiation and focuses on the radiation safety of patients. There is a continuous need for research because of the rapid progress of examination and treatment methods. Research on non-ionizing radiation focuses on the exposure determination methods necessary for regulatory control and the development of regulations.

STUK has been active in its efforts to expand the pool of competence in Finnish radiation safety research. In October 2015, STUK and nine Finnish universities established a consortium for radiation safety research co-ordinated by STUK. The consortium aims to secure the continuation of high-quality radiation safety research in Finland through closer co-operation. A national programme, which describes the key research needs, was prepared and published in June to serve as the foundation for the consortium. In 2016, STUK made preparations to join the agreement on the Helsinki Institute of Physics. The agreement will enable closer co-operation in radiation safety research and more flexible use of research resources.

University and hospital partners were also encouraged to take part in international research consortia and funding application processes related to radiation safety and radiation metrology.

Research and development work was carried out through the following projects:

STUK participated in the work of the EURADOS working groups 2 (Harmonization of individual monitoring), 7 (Internal dosimetry), 9 (Radiation dosimetry in radiotherapy) and 12 (Dosimetry in medical imaging). The work of the EURADOS working groups focused on the assessment and development of employee dosimetry methods, the development of patient dosimetry methods in interventional radiology and cardiology and the computational dosimetry of imaging. In patient dosimetry, particular attention was paid to the possibility of setting alarm limits for the monitoring of a patient's skin dose, so that the dose will not exceed the risk limit for skin damage. A proposal on alarm limits was prepared and will be published in 2017. The EURADOS co-operation also involved preparations for a project that investigates patient doses caused by imaging in radiotherapy. STUK participates in the computational determination of patient doses.

Within the scope of the EURALOC project, funded by the EU, STUK measured eye lens doses to cardiologists at Finnish hospitals. The collection of the research data has been completed. The participants in the study were 274 cardiologists who had been exposed to radiation at work and 128 non-exposed reference persons from nine European countries. In addition, the data of two previously conducted studies, one of them Finnish and one French, will be included in the research data. The study subjects were examined by an ophthalmologist to evaluate lens opacity. In addition, the lens was imaged, and a lens permeability measurement was carried out on some subjects. Doses to the eye have been evaluated on the basis of job history (the number of different types of examinations). The project will be completed in 2017.

STUK published a report on the dose to population in Finland from the medical use of

radiation (X-ray diagnostics and interventional radiology). The report was based on the frequencies of radiological examinations and procedures in Finland in 2008. According to the report, the collective effective dose to population in Finland in 2008 from all X-ray examinations and procedures was approximately 2 397 000 mSv, resulting in the effective dose per caput of 0.45 mSv. Computed tomography (CT) examinations make by far the highest contribution to the total population dose; they account for approximately 58% of the total population dose.

STUK implemented a project partially funded by the Ministry of Social Affairs and Health on limiting exposure to ultrasound. The project surveyed the applications of ultrasound and the related safety issues as part of the preparation of the revision of the Radiation Act. On the basis of the results of the survey, a proposal was prepared for limiting non-medical exposure to ultrasound. The final report of the project will be submitted to the Ministry of Social Affairs and Health in January 2017.

STUK surveyed electric fields in the vicinity of power lines analytically and by field measurements. The results of the survey will particularly be used by the comprehensive Radiation Act revision project. The results will be published in the STUK-TR series of technical reports early in 2017.

STUK participated in the ERAMUS+-funded EBreast project. Its main objective is to survey and develop the training of personnel participating in the treatment chain of breast cancer, from early diagnosis to follow-up. STUK is responsible for the improvement of radiation safety and quality assurance skills in screening mammography and clinical mammography. The project will be completed in 2018.

STUK assessed doses to the eye in a group of employees exposed to radiation in nuclear medicine. The assessments were carried out using thermoluminescence. The results will be used in practical radiation surveillance and the radiation protection of personnel. The measurements will be completed in 2017.

European Metrology Programme for Innovation and Research EMPIR

The EU-funded MetroNORM project (Metrology for processing materials with high natural radioactivity) develops accurate, traceable and standardized methods for measuring natural radioactive materials that emit ionizing radiation in laboratories, radiation monitoring locations and the field. STUK is involved in the standardization of the calibration and reference samples prepared in the project and the production of a new measurement device to detect alpha radiation on various surfaces in field and laboratory conditions. The measurement device is also suitable for use in abnormal events where lengthy radiochemical sample processing is not required. The project, completed in 2016, was executed as planned for STUK's part.

A perfusion imaging dosimetry project was launched in summer 2016. STUK participates in the development of patient-specific CT dosimetry in co-operation with PTB from Germany and the University of Helsinki. The objective is to develop measurement and computational methods to be used in daily work with patients.

STUK participated in the Normative application process for 2016, resulting in the approval of a project to develop dosimetry in radiotherapy (review of the ionization chamber response in modern radiotherapy beams). The project will start in May 2017 and run for two years.

Patient skin dose and staff doses in interventional radiology and cardiology

Together with Finnish university hospitals and central hospitals, STUK measured patients' radiation exposure, including measurement of skin doses to patients and personnel's exposure to radiation in cardiological examinations and procedures. The cardiological diagnostic reference levels were updated on the basis of the results in the latter part of 2016. The comprehensive measurements made it possible to assign reference levels to examinations and procedures with very few previously determined reference levels, even on an international scale. The survey was expanded to cover 12 European countries (EURADOS collaboration). The results of the international project will be published in 2018.

STUK also participated in EURADOS co-operation, which has involved developing a method for measuring patient skin doses in interventional radiology and cardiology. One of the objectives is to study whether a joint European alarm limit

can be set for skin doses to prevent skin damage to patients. The results of the project have been submitted for publication.

Within the scope of the EURALOC project, STUK has measured the eye lens doses to cardiologists at three Finnish hospitals. STUK is also involved in determining the cataract risk in cardiologists.

Other research activities

STUK has collaborated with the Helsinki Institute of Physics to study the responses of various types of position-sensitive detectors at high dose rates in photon beams. This is a preliminary survey for a project to be launched in 2017 to develop real-time 3D measuring methods for radiotherapy.

STUK and Helsinki University Hospital have collaborated to survey the exposure of radiation-using employees and the probability of potential exposure.

7 International co-operation

Participation in the work of international organizations and commissions

Representatives of the Department of Radiation Practices Regulation are involved in a number of international organizations and commissions dealing with the regulatory control and the development of safety instructions and measuring methods relating to the use of ionizing and non-ionizing radiation, and in standardizing activities in the field of radiation. These organizations and commissions include IAEA, NACP, EURADOS, EURAMET, ESTRO, ESOREX, AAPM, IEC, ISO, CEN, CENELEC, ICNIRP, EAN, EUTERP, HERCA, EURATOM/Article 31 Group of Experts, WHO, UNSCEAR.

The Department of Radiation Practices Regulation participated in the European Commission's PiDRL project, which prepared the EU's recommendation on radiation exposure reference levels for paediatric radiological examinations and procedures.

Participation in meetings of international working groups

In 2016, representatives from STUK participated in the meetings of the following international organizations and working groups:

- EURAMET (European Association of National Metrology Institutes) annual meeting of contact persons
- Meeting of the Nordic Dosimetry Group
- The "Personal dosimetry workshop" seminar of Nordic radiation protection authorities from 11 to 12 October 2016
- Meeting of the group on the use of radiation in Nordic health care sector (Nordic group for medical applications)
- HERCA (Heads of the European Radiological Protection Competent Authorities) and its working groups
- The annual meeting of EURADOS (European Radiation Dosimetry Group) and its working groups
- NORGIR meeting (Nordic Working Group on Industrial Radiation)
- EACA meeting (European Association of Competent Authorities on the transport of radioactive material)
- ICNIRP (International Commission on Non-Ionizing Radiation Protection)
- NACP Radiation Physics Committee
- Nordic Ozone Group (incl. UV matters)
- NIR seminar of the Nordic radiation protection authorities in Oslo
- WHO EMF project and InterSun Programme; international advisory group
- IEC TC 61 MT 16 meeting (sunbed standards)
- IAEA: Transport Safety Standards Committee
- IAEA: Radiation Safety Standards Committee.

8 Co-operation in Finland

Participation in the work of Finnish organizations and commissions

Representatives of STUK are involved in many Finnish organizations and commissions that deal with the regulatory control and research of the use of ionizing and non-ionizing radiation, and with standardization activities in the field of radiation. These include the Advisory Committee on Metrology, the Radiation Safety Conference Committee, the Education Committee of Medical Physicists, Eurolab-Finland, SESKO and the Finnish Advisory Committee for Clinical Audit (KLIARY) funded by the Ministry of Social Affairs and Health and appointed by the National Institute for Health and Welfare, the Screening Committee, SOTERKO and the Environmental Intolerance Network. STUK experts take part in several meetings in the field of radiation safety in Finland every year, giving presentations and lectures.

Participation in meetings of Finnish working groups

In 2016, representatives from STUK participated in the meetings of the following Finnish organizations and working groups:

- Subordinate working groups of the Ministry of Social Affairs and Health for the comprehensive revision of radiation legislation
- The Screening Committee of the Ministry of Social Affairs and Health and its subordinate working group preparing the decree amendment.
- Environmental Intolerance Network of the Ministry of Social Affairs and Health
- SESKO SK 61 committee (safety of domestic electrical appliances)
- SESKO SK 106 committee (electromagnetic fields)
- The Radiation Safety Committee of the Finnish Defence Forces (NIR matters)
- The Education Committee of Medical Physicists (radiation protection matters).

Finnish conferences arranged by STUK

In 2016, STUK arranged the following conferences:

- Radiotherapy physicists' conference 9–10 June 2016 in Helsinki
- Conference day for radiation source vendors and maintenance staff 9 November 2016 in Helsinki.

Other co-operation in Finland

STUK engaged in regulatory control co-operation with the National Supervisory Authority for Welfare and Health (VALVIRA) and with Regional State Administrative Agencies.

A STUK representative served as a member and secretary in the Finnish Advisory Committee for Clinical Audit (KLIARY), appointed by the National Institute for Health and Welfare (THL) and funded by the Ministry of Social Affairs and Health (STM). The STUK representative is also responsible for the maintenance of the group's website. The activities of the group included arranging a seminar on the development of clinical auditing and preparing a recommendation concerning advanced clinical audits of units performing radiological examinations. In addition, the group participated in the development of information systems for clinical audits, so that national summaries of the implementation and results of clinical audits would be easily accessible through information systems in the future. The recommendation and more information on the group's activities can be found on the group's website (www.clinicalaudit.net).

9 Communication

In 2016, STUK received a number of radiation-related questions through its website and by phone from citizens, radiation users, the media and other parties interested in radiation. Most of the questions were related to non-ionizing radiation. Several interviews on current radiation topics were given to the media.

The harmful effects of UV radiation were actively communicated. STUK participated in the UV press event, which was the 14th consecutive UV event arranged jointly by STUK, the Cancer Society of Finland and the Finnish Meteorological Institute. The topics of the event included skin cancer statistics, protection against UV radiation in summer jobs, the popularity of sun tanning among the young and the UV index. The press release published of the event received wide media coverage, and many reporters were present at the event. Communication related to non-ionizing radiation was refined through the improvement of the materials published on STUK's website.

Press releases and online news articles were prepared by the staff of the Radiation Practices Regulation Department on the following topics:

- Accident in Tikkakoski when handling radioactive iodine
- The Ministry of Social Affairs and Health to request opinions on the proposal for the new Radiation Act
- Focus on the justification of X-ray examinations – it is time to act!
- Faulty coupling of X-ray appliance caused minor extra radiation exposure in chest X-ray
- All lessons will be learned from the March cesium incident
- Tanning is a cancer risk
- Damaged cesium source now confined in the warehouse of Suomen Nukliditekniikka
- No abnormalities detected in environmental measurements
- Premises are being reclaimed and investigation continues
- Cesium 137 now traced back to the property's garage and parts of its basement premises
- STUK: No observations departing from the normal elsewhere in Finland; the concentration in Helsinki has normalized.

In 2016, STUK published one newsletter aimed at health care professionals and two newsletters aimed at industry professionals engaged in radiation practices. The objective is to make the newsletter an integral part of communication.

The preparation of a guide concerning the safety of using radiation in cardiology was initiated in 2015 by establishing a working group including cardiology specialists from outside STUK (cardiologists, physicists and a radiographer). The guide will be completed in autumn 2017.

10 Metrological activities

10.1 General

STUK serves as the national metrological laboratory for radiation dose quantities. STUK maintains national and other measurement standards to ensure the accuracy and traceability of radiation measurements carried out in Finland. STUK calibrates its own standards at regular intervals at the International Bureau of Weights and Measures (BIPM) or other primary laboratories. In the field of radiation metrology, STUK is involved in the work of the Advisory Committee on Metrology and the European Association of National Metrology Institutes (EURAMET). Furthermore, STUK participates in the international equivalence agreement (CIPM–MRA), the implementation of which is coordinated in Europe by EURAMET, and in the network of secondary standard dosimetry laboratories (SSDL), which is jointly coordinated by IAEA and WHO.

Metrological activities are the responsibility of STUK's Radiation Metrology Laboratory for ionizing radiation and the NIR Unit for non-ionizing radiation. Metrology of ionizing radiation activity quantities is the responsibility of the Department of Environmental Radiation Surveillance and Emergency Preparedness (VALO) at STUK.

Maintenance of metrological standards and development of irradiation apparatus and measurement methods

Irradiation equipment and national metrological standards were maintained for calibrations of radiation meters for radiotherapy, radiation protection and X-ray imaging. The automatic control for controlling irradiation equipment was replaced.

Meter and measurement comparisons

STUK participated in three EURAMET calibration comparisons performed on different X-radiation types. The measured parameter was air kerma. Results are available from one comparison. STUK's results were excellent, efficiently supporting STUK's calibration activities. The analyses of the results of two comparisons are still ongoing.

STUK took part in the annual TLD dosimetry audit measurement of the absorbed doses of Co-60 gamma radiation (radiotherapy dose accuracy), which is organized by the IAEA/WHO for network of calibration laboratories, and the OSDL comparison of Co-60 gamma radiation, arranged every three years. In both comparisons, STUK's results deviated very little from the reference value (0.2 and -0.9 per cent, respectively) and were well within the acceptable variation of the results as defined by the IAEA and the laboratory. Figure 10 shows the deviations from the reference value in the TLD comparison from 2001 to 2016.

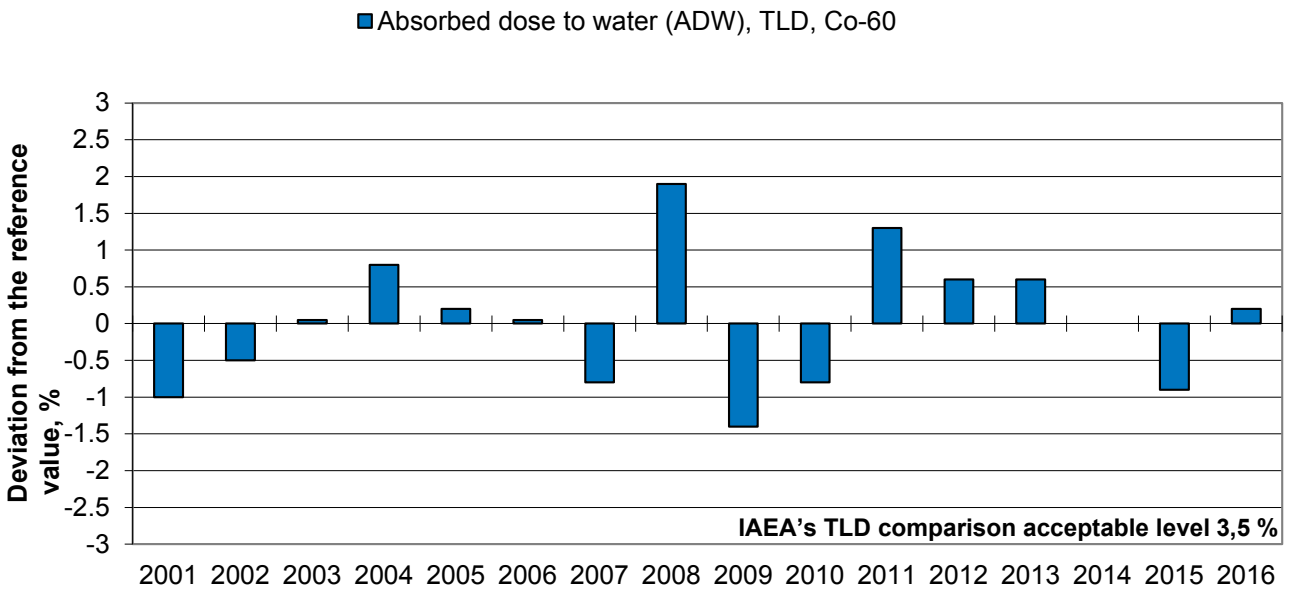

Figure 10. TLD comparison results 2001–2016. The results are shown as deviation (%) from the reference value. IAEA's acceptable level for the results is 3.5%.

11 Services

Calibration, testing and irradiation

Radiation meter calibrations and testing were performed on request. Altogether 157 radiation meter calibration, inspection and testing certificates and 44 irradiation certificates were issued. The number of samples irradiated was 1203. Approximately 15% of the calibrations were performed on STUK's own instruments and samples.

The Non-Ionizing Radiation Surveillance Unit performed a total of eight radiation meter calibrations and tests, along with four safety assessments and radiation measurements. The service output of the NIR Unit from 2007 to 2016 is shown in Table 14 of Appendix 1.

Other services

The PCXMC computer application designed for calculating patient doses in X-ray diagnostics was further developed, and 49 copies were sold.

APPENDIX 1 TABLES

Table 1. Radiation practices in the use of radiation in health care and veterinary practices at the end of 2016.

Use of radiation	Number of practices
X-ray practices	300
Veterinary X-ray practices	249
Challenging X-ray practices	93
C-arm practices	83
Small-scale X-ray practices	1484
X-ray practices outside X-ray departments	52
Screening with X-rays	56
Use of unsealed sources	25
Use of unsealed sources (veterinary)	2
Use of sealed sources	25
Use of sealed sources (veterinary)	1
Radiotherapy	13

Table 2. Radiation sources and appliances and radionuclide laboratories in the use of radiation in health care and veterinary practices at the end of 2016.

Appliances/Sources/Laboratories	Number
X-ray diagnostic appliances (generators)*)	**1586**
fixed conventional X-ray appliances	490
portable fluoroscopy appliances	275
portable conventional X-ray appliances	169
mammography appliances, of which	168
• screening mammography	84
• tomosynthesis	10
fixed fluoroscopy appliances, of which	111
• angiography	48
• fluoroscopy	29
• cardioangiography	42
CT-appliances, of which	128
• SPECT-CT	34
• PET-CT	14
CBCT appliances (other than dental imaging)	16
O-arm appliances	8
dental X-ray appliances (other than conventional dental imaging), of which	160
• CBCT appliances	89
• panoramic scanners	97
• conventional dental X-ray appliances	32
bone mineral density measurement appliances	57
other appliances	4
Dental X-ray appliances (conventional dental X-ray practices)	**5906**
conventional dental X-ray appliances	5240
panoramic scanners	651

Radiotherapy appliances	**151**
accelerators	44
X-ray imaging appliances	44
afterloading appliances	7
manual afterloading appliances	3
X-ray therapy appliances	1
radiotherapy simulators	15
sealed sources (check sources)	37
Sealed sources	**312**
calibration and testing equipment	300
attenuation correction units	6
gamma irradiators	2
other sealed sources in health care	4
X-ray appliances in veterinary practices	**403**
conventional X-ray appliances	300
bone mineral density measurement appliances	0
fluoroscopy appliances	2
intra oral appliances	91
CT scanners, of which	10
• SPECT-CT	0
• PET-CT	0
other appliances	0
Radionuclide laboratories	**36**
B-type laboratories	27
C-type laboratories	9

*) An X-ray diagnostic appliance comprises a high voltage generator, one or more X-ray tubes and one or more examination stands.

Table 3. Radiation practices in the use of radiation in industry, research and education at the end of 2016.

Use of radiation	Number
Use of sealed sources	556
Use of X-ray appliances	604
Installation, test operations and services	186
Importing and exporting of radioactive materials or trading in them	113
Trade in X-ray appliances	30
Use of unsealed sources	86
Use of particle accelerators	18

Table 4. Radiation sources and appliances and radionuclide laboratories in the use of radiation in industry, research and education at the end of 2016.

Appliances/Sources/Laboratories	Number
Appliances containing radioactive materials	**5882**
level switches	1876
continuous level gauges	1100
density gauges	971
weight scales	620
basis weight meters	449
appliances or sources used for calibration, testing or education	351
moisture and density gauges	109
particle analyzers	72
fluorescense analyzers	47
radiography appliances	19
other appliances	268
X-ray appliances	**1862**
fluoroscopy appliances	767
diffraction and fluorescense analyzers	551
radiography appliances	381
basis weight meters	45
other X-ray appliances	118
Accelerators	**27**
fluoroscopy	16
research	6
manufacturing of radioactive materials	5
Radionuclide laboratories	**115**
A-type laboratories	7
B-type laboratories	25
C-type laboratories	80
activities outside laboratories (tracer element tests in industrial plants)	3

Table 5. Radionuclides most commonly used in sealed sources in industry, research and education at the end of 2016.

Radionuclide	Number of sources
Other than high-activity sealed sources	
Cs-137	4110
Co-60	941
Am-241 (gamma sources)	322
Kr-85	312
Fe-55	110
Am-241 (AmBe neutron sources)	102
Sr-90	99
Pm-147	90
Ni-63	76
High-activity sealed sources	
Cs-137	55
Co-60	29
Ir-192	10
Am-241 (gamma sources)	9
Sr-90	5
Am-241 (AmBe neutron sources)	5

Table 6. Deliveries of sealed sources to and from Finland in 2016

Radionuclide	Deliveries to Finland		Deliveries from Finland	
	Activity (GBq)	Number	Activity (GBq)	Number
Ir-192	46 022	23	2275	22
Se-75	2220	1	< 1	1
Kr-85	1495	101	1169	79
Fe-55	138	28	95	19
Cs-137	91	60	-**)	-
Ni-63	47	126	10	27
Pm-147	25	37	3	15
I-125	24	*)	-	-
Am-241	13	36	2	295
Gd-153	10	14	-	-
Sr-90	7	20	4	7
Co-57	6	48	-	-
Ge-68	4	13	-	-
Co-60	3	17	-	-
others total ***)	< 1	15	-	-
Total	**50 107**	**539**	**3558**	**465**

*) The exact number of small sources of I-125 used in radiotherapy is not known.
**) The symbol "-" indicates no deliveries from Finland.
***) Nuclides: Cf-252, Po-210, Ru-106, Ba-133 and Na-22.

Table 7. Manufacturing of radioactive substances (unsealed sources) in Finland in 2016.

Radionuclide	Activity (GBq)
F-18	207 772
C-11	23 040
O-15	6350
Cu-64	38
Total	**237 200**

Table 8. Number of air crew members subject to individual monitoring of radiation exposure and total dose of crew members (sum of effective doses) in 2012–2016.

Year	Number of workers		Total dose (Sv)	
	Pilots	Cabin crew	Pilots	Gabin crew
2012	1182	2419	2.60	5.80
2013	1184	2596	2.79	6.02
2014	1213	2441	2.74	5.93
2015	1153	2527	2.66	6.09
2016	1118	2534	2.95	7.24

Table 9. Number of workers subject to individual monitoring in 2012–2016.

Year	Number of workers in various sectors								
	Health care		Veterinary practices	Industry	Research and education	Manufacturing of radioactive materials	Others*)	Use of nuclear energy**)	Total***)
	Exposed to X-radiation	Exposed to other radiation sources							
2012	3989	1083	582	1286	720	22	107	3676	11 341
2013	3953	1147	636	1329	727	20	125	3715	11 540
2014	3743	1243	653	1257	686	22	143	3621	11 197
2015	3631	1244	664	1371	649	26	142	3291	10 800
2016	3548	1218	703	1322	644	27	163	3511	10 951

*) Sectors included: installation/servicing/technical test runs, trade/import/export and services.

**) Finns working at nuclear power plants in Finland and abroad and foreign workers working at Finnish facilities.

***) The figures shown in a certain row of this column is not necessarily the same as the sum of figures in other columns of the same row, as some health care staff are exposed both to X-radiation and other forms of radiation, and there are workers in industry who also work in the use of nuclear energy.

Table 10. Total doses (sums of $H_p(10)$ values) of workers subject to individual monitoring in 2012–2016.

Year	Total dose in various sectors (Sv)								
	Health care		Veterinary practices*)	Industry	Research and education	Manufacturing of radioactive materials	Others**)	Use of nuclear energy***)	Total
	Exposed to X-radiation*)	Exposed to other radiation sources							
2012	1.33	0.10	0.12	0.16	0.05	0.007	0.001	2.47	4.23
2013	1.24	0.09	0.12	0.14	0.04	0.005	0.002	1.25	2.90
2014	1.29	0.08	0.11	0.16	0.04	0.019	0.007	1.57	3.28
2015	1.27	0.10	0.13	0.18	0.03	0.011	0.003	1.35	3.07
2016	1.22	0.08	0.13	0.16	0.04	0.016	0.007	1.81	3.46

*) $H_p(10)$ values are generally (sufficiently accurate) approximations of the effective dose. One exception to this is the use of X-radiation in health care and veterinary practices in which workers use personal protective shields and in which the dose is measured by a dosemeter on the exposed side of the shield. The effective dose is then obtained by dividing the $H_p(10)$ values by a factor between 10 and 60.

**) Sectors included: installation/servicing/technical test runs, trade/import/export and services.

***) Finns working at nuclear power plants in Finland and abroad and foreign workers working at Finnish facilities.

Table 11. Data (H_p (10) values) on certain occupational groups in 2016.

Group	Number of workers	Total dose (Sv)	Average dose (mSv)		Largest dose (mSv)
			Workers whose dose exceeds recording level*)	All workers subject to individual monitoring	
Cardiologists and interventional cardiologists**)	211	0.60	3.6	2.7	17.7
Interventional radiologists**)	31	0.22	9.1	7.0	24.9
Radiologists**)	298	0.22	3.3	0.7	14.0
Consultant specialists**) ***)	314	0.06	1.0	0.2	5.3
Nurses**)	1100	0.05	0.4	0.0	2.5
Radiographers (X-rays)**)	1151	0.03	0.4	0.0	2.4
Radiographers (other than X-rays)	538	0.06	0.7	0.1	3.0
Veterinary nurses and assistants**)	432	0.07	1.1	0.2	6.1
Veterinary surgeons**)	270	0.05	1.4	0.2	6.5
Industrial material inspection technicians****)	544	0.10	0.7	0.2	3.9
Industrial tracer testing technicians	24	0.04	3.3	1.8	7.9
Nuclear power plant workers					
• insulation work	58	0.16	3.2	2.7	10.7
• mechanical duties and machine maintenance	662	0.58	1.4	0.9	9.1
• cleaning	220	0.21	1.8	1.0	8.1
• material inspection	222	0.18	1.3	0.8	9.5
• electrial and automation work	671	0,14	0.7	0.2	5.6
• radiation protection	77	0.12	2.0	1.5	8.6

*) Recording level is 0.1 mSv per month or 0.3 mSv per 3 months.

**) H_p(10) values are generally (sufficiently accurate) approximations of the effective dose. One exception to this is the dose sustained by these working groups. Workers engaged in the use of radiation (X-rays) in health care and in veterinary practices use personal protective shields, and the dose is measured by a dosemeter on the exposed side of the shield. The effective dose is then obtained by dividing the H_p(10) value by a factor between 10 and 60.

***) Including surgeons, urologists, orthopedists, neuroradiologists and gastroenterologists.

****) Exposure arising elsewhere than in nuclear power plant.

Table 12. The principal radioactive waste in the national storage facility for low-level waste (31 December 2016).

Radionuclide	Activity (GBq) or mass
H-3	26 616
Cs-137	2820
Am-241	2202
Pu-238	1505
Kr-85	1414
Am-241 (Am-Be)	603
Ra-226	235
Sr-90	212
Cm-244	143
Co-60	88
Fe-55	32
Ni-63	33
C-14	18
Pu-234 (Pu-Pe)	7
U-238 *)	1284 kg
Th-323	2.5 kg
*) Depleted uranium	

Table 13. The work of the NIR Unit in regulatory control of the use of non-ionizing radiation in 2007–2016.

Year	Regularoty inspections	Decisions	Statements	Prohibitions of dangerous laser devices sold on the internet	Total
2007	64	3	3		70
2008	67	5	6		78
2009	47	2	9	15	73
2010	55	3	9	31	98
2011	56	6	3	42	107
2012	53	0	15	43	111
2013	63	3	11	42	119
2014	53	2	23	41	119
2015	68	1	14	14	97
2016	72	2	10	18	102

Table 14. The service work of the NIR Unit in 2007–2016.

Year	Calibrations and tests	Safety assessments and radiation measurements	Total
2007	33	17	50
2008	46	24	70
2009	31	12	43
2010	36	13	49
2011	4	10	14
2012	8	16	24
2013	5	5	10
2014	6	8	14
2015	2	7	9
2016	8	4	12

Table 15. Inspections of sunbed facilities in 2007–2016. In addition to STUK's own inspections in 2012–2016, also health inspectors of municipalities inspected the sunbed facilities in 2013–2016 and submitted reports of their findings concerning radiation safety to STUK for decision-making. In brackets there is the number of STUK's decisions. It was also investigated by requests for clarification from responsible parties, if their practices were in accordance with the requirements.

Year	Number of inspections
2007	31
2008	26
2009	19
2010	16
2011	7
2012	6 (16)
2013	3 (40)
2014	1 (20)
2015	4 (17)
2016	4 (55)

Table 16. SAR tests of mobile phones and other wireless devices in 2007–2016.

Year	Number of tests
2007	15
2008	10
2009	15
2010	10
2011	5
2012	15
2013	11
2014	10
2015	14
2016	11

APPENDIX 2

PUBLICATIONS IN 2016

The electronic publication archive Julkari (julkari.fi) features STUK's serial publications in PDF format. Julkari also serves as a publication register. For this reason, only metadata is available for some publications.

The following publications were completed in 2016:

Scientific articles by STUK employees

Barquinero Joan Francesc, Beinke Christina, Borràs Mireia, Buraczewska Iwona, Darroudi Firouz, Gregoire Eric, Hristova Rositsa, Kulka Ulrike, Lindholm Carita, Moreno Mercedes, Moquet Jayne, Oestreicher Ursula, Prieto Jesús M, Pujol Mònica, Ricoul Michelle, Sabatier Laure, Sommer Sylwester, Sun Mingzhu, Wojcik Andrzej, Barrios Leonardo. RENEB biodosimetry intercomparison analyzing translocations by FISH. International Journal of Radiation Biology 2016. http://dx.doi.org/10.1080/09553002.2016.1222092 (Published online: 05 Oct 2016.).

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Finnish language

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Säteilytoiminta ja säteilymittaukset. Ohje ST 1.9. (Radiation practices and radiation measurements. Guide ST 1.9) STUK (23 November 2016).

Umpilähteiden ja niitä sisältävien laitteiden säteilyturvallisuus. Ohje ST 5.1. (Radiation safety of sealed sources and equipment containing them. Guide ST 5.1) STUK (13 September 2016).

Säteilylähteiden kauppa. Ohje ST 5.4. (Trade in radiation sources. Guide ST 5.4) STUK (14 June 2016).

Säteilyturvallisuus avolähteiden käytössä. Ohje ST 6.1. (Radiation safety when using unsealed sources. Guide ST 6.1) STUK (2 March 2016).

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APPENDIX 3

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General guides

ST 1.1 Safety in radiation practices, 23 May 2013
ST 1.3 Warning signs for radiation sources, 9 December 2013
ST 1.4 Radiation user's organization, 2 November 2011
ST 1.5 Exemption of radiation use from safety licensing, 12 September 2013
ST 1.6 Operational radiation safety, 10 December 2009
ST 1.7 Radiation protection training in health care, 10 December 2012
ST 1.8 Qualifications and radiation protection training of persons working in a radiation user's organization, 25 January 2016
ST 1.9 Radiation practices and radiation measurements, 17 March 2008
ST 1.10 Design of rooms for radiation sources, 14 July 2011
ST 1.11 Security arrangements of radiation sources, 9 December 2013

Radiation therapy

ST 2.1 Safety in radiotherapy, 18 April 2011

Diagnostic radiology

ST 3.1 Dental X-ray examinations in health care, 13 June 2014
ST 3.3 X-ray examinations in health care, 8 December 2014
ST 3.8 Radiation safety in mammography examinations, 25 January 2013

Industry, research, education and commerce

ST 5.1 Radiation safety of sealed sources and devices containing them, 7 November 2007
ST 5.2 Use of control and analytical X-ray apparatus, 26 September 2008
ST 5.3 Use of ionising radiation in the teaching of physics and chemistry, 4 May 2007
ST 5.4 Trade in radiation sources, 19 December 2008.
ST 5.6 Radiation safety in industrial radiography, 9 March 2012
ST 5.7 Shipments of radioactive waste and spent fuel, 6 June 2011
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Unsealed sources and radioactive wastes

ST 6.1 Radiation safety when using unsealed sources, 2 March 2016
ST 6.2 Radioactive wastes and discharges, 3 October 2014
ST 6.3 Radiation safety in nuclear medicine, 14 January 2013

Radiation doses and health surveillance

ST 7.1 Monitoring of radiation exposure, 14 August 2014
ST 7.2 Application of maximum values for radiation exposure and principles for the calculation of radiation doses, 8 August 2014
ST 7.3 Calculation of the dose caused by internal radiation, 13 June 2014
ST 7.4 The dose register and data reporting, 8 December 2014
ST 7.5 Medical surveillance of occupationally exposed workers, 13 June 2014

Veterinary medicine

ST 8.1 Radiation safety in veterinary X-ray examinations, 20 March 2012

Non-ionizing radiation

ST 9.1 Radiation safety requirements and regulatory control of tanning appliances, 1 July 2013 (in Finnish)
ST 9.2 Radiation safety of pulsed radars, 2 September 2003 (in Finnish)
ST 9.3 Radiation safety during work on masts at FM and TV stations, 2 September 2003 (in Finnish)
ST 9.4 Radiation safety of laser displays and shows, 30 April 2015

Natural radiation

ST 12.1 Radiation safety in practices causing exposure to natural radiation, 2 February 2011
ST 12.2 The radioactivity of building materials and ash, 17 December 2010
ST 12.4 Radiation safety in aviation, 1 November 2013

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